DIVISION 16

ELECTRICAL

SECTION 16015 - ELECTRICAL SYSTEMS ANALYSIS

PART 1 – GENERAL

1.01 SCOPE OF WORK

A. The requirements of this specification shall apply to the new electrical distribution system at West Hickman Wet Weather Storage Facility (WHWWSF)-. The end result shall be a fully protected, and properly coordinated, system with proper arc flash safety labels and personal protective equipment recommendations.

B. Contractor shall furnish short-circuit and protective device coordination studies as described herein. The coordination study shall begin with the utility company's feeder protective device and include all of the electrical protective devices down to, and including, the main breaker and feeder circuit in each 208 Volt panelboard. The study shall also include variable frequency drives, harmonic filters, power factor correction equipment, transformers and protective devices associated with variable frequency drives, emergency and standby generators associated paralleling equipment and distribution switchgear.

C. The contractor shall furnish an Arc Flash Hazard Analysis Study per NFPA 70E - Standard for Electrical Safety in the Workplace, reference Article 130.3 and Annex D. Provide Arc Flash label as shown on section 3.02 of this specification.

D. Contractor shall provide Ethernet capable power monitoring equipment for all new MCCs and MCCs which are modified.

1.02 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

   a. IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems.

   b. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings.

   c. IEEE 242: Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.

   d. IEEE 399: Recommended Practice for Industrial and Commercial Power System Analysis.

   e. IEEE 1015 – Recommended Practice for Applying Low Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.

   f. IEEE 1584-2002: Guide for Performing Arc Flash Hazard Calculations.

2. American National Standards Institute (ANSI):

   a. C57.12.00, Standard General Requirements for Liquid immersed Distribution, Power, and Regulating Transformers.

   b. ANSI C37.13 – Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures.

c. ANSI C37.010 – Standard Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

d. ANSI C 37.41 – Standard Design Tests for High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories.

e. ANSI C37.5 – Methods for Determining the RMS Value of a Sinusoidal Current Wave and Normal-Frequency Recovery Voltage, and for Simplified Calculation of Fault Currents.

3. National Fire Protection Association:

a. NFPA 70E: National Electrical Safety Code Chapter 1.

b. NFPA 70: National Electrical Code.

4. Occupational Safety & Health Administration (OSHA):

a. 29-CFR, Part 1910, sub part S.

1.03 SUBMITTALS

A. Shop drawings: the results of the short-circuit, protective device coordination, and arc flash hazard analysis studies shall be summarized in a preliminary and final summary report. Submit five (5) three-ring binder bound copies of the complete preliminary and final study reports. The preliminary short circuit and device coordination study report shall be submitted within 30 days of notice to proceed and shall be a basis for approval of all other electrical equipment in the power distribution system. The contractor is expected to review the results of the preliminary short circuit and device coordination study report against all other applicable shop drawings, including industrial control panels, prior to shop drawing submittal to coordinate appropriate fault duty ratings of all electrical equipment. The final short circuit and device coordination study report shall incorporate all comments from shop drawing submittals and include the arc-flash hazard analysis. The contractor shall ensure proper arc-flash warning labels are applied to all appropriate electrical equipment when the final study has been approved.

1.04 QUALITY ASSURANCE

A. Short circuit, protective device coordination, and arc flash studies shall be prepared by the manufacturer furnishing the electrical power distribution equipment or a professional electrical engineer registered in the State of Kentucky, hired by the manufacturer, in accordance with IEEE 242 and IEEE 399.

B. Manufacturer shall have unit responsibility for the equipment and protective device coordination.

1.05 SEQUENCING AND SCHEDULING

A. An initial, complete short circuit and arc flash study must be submitted and reviewed before Engineer will approve Shop Drawings for switchgear, unit sub stations, breakers, MCC'S, switchboard, VFD'S, manufactured industrial control panels and circuit breaker panelboard equipment. Failure to do so will delay the approval of major equipment submittals.

B. The short circuit, protective device coordination and arc flash studies shall be updated prior to Project Substantial Completion. Utilize characteristics of as-installed equipment actual wire run lengths and materials.

PART 2 - PRODUCTS

2.01 GENERAL

A. Contractor shall furnish all field data as required for the power system studies. The Engineer performing the short-circuit, protective device coordination and arc flash hazard analysis studies shall furnish the Contractor with a listing of required data immediately after award of the contract. The Contractor shall expedite collection of the data to eliminate unnecessary delays and assure completion of the studies as required for final approval of the distribution equipment shop drawings and/or prior to the release of the equipment for manufacturing. Contractor shall contact the Owner for the existing available data from the previous projects and field verify/collect all other necessary for the studies.

B. Source combination may include present and future utility supplies, motors, and generators.

C. Load data utilized may include existing and proposed loads obtained from Contract Documents provided by Owner or Contractor.

D. Equipment and component titles used in the studies shall be identical to the equipment and component titles shown on the Drawings.

E. Perform studies using digital computer with a software package such as SKM Power*Tools for Windows™ DAPPER™, CAPTOR™ and ARC FLASH™, or approved equal.

F. Perform complete fault calculations for all busses on utility and generator power sources. Perform load flow and voltage drop studies for major feeders and loads with long feeder runs. Analysis shall include expected fault currents at industrial control panels manufactured in accordance with UL 508A and NEC article 409.

G. Fault source combinations shall include large motors, large transformers, utility and generator.

H. Utilize proposed and existing load data for the study obtained from Contract Documents and field survey. Coordinate with local power utility for available fault currents from utility services.

I. Existing Equipment:

1. Include fault contribution of all existing equipment including, but not limited to, existing motors, services, distribution equipment, as appropriate, in the study.

2. Obtain required existing equipment data from the field and local power utility.

J. Provide a comprehensive report document containing the short circuit, device coordination and arc flash studies. As a minimum the report structure shall contain the following:

1. Executive Summary.

2. Methodology.

3. One Line Diagram(s).

4. Short Circuit Analysis.

5. Short Circuit Analysis Results/Conclusions/Recommendations.

6. Device Coordination Analysis.

7. Recommended protective devices settings.

8. Arc Flash Analysis.

9. Arc Flash PPE recommendations.

2.02 SHORT CIRCUIT STUDY

A. General:

1. Use cable impedances based on copper conductors. Use actual conductor impedances if know. If unknown, use typical conductor impedances based on IEEE Standards 141, latest edition.

2. Use bus impedances based on copper bus bars.

3. Use cable and bus resistances calculated at 25 degrees C.

4. Use 600-volt cable reactances based on use of typical data of conductors to be used in this project.

5. Use transformer impedances 92.5 percent of "nominal" impedance based on tolerances specified in ANSI C57.12.00.

B. Provide:

1. Calculation methods and assumptions.

2. Selected base per unit quantities.

3. One-line diagrams annotated with results of short circuit analysis including:

a. Three phase, line-to-line and single line to ground faults.

b. Equipment Short Circuit Rating.

4. Source impedance data, including electric utility system and motor fault contribution characteristics.

5. DAPPER™ Short circuit report, demand load report, load flow report and input data reports.

6. Results, conclusions, and recommendations.

A. Calculate short circuit interrupting and momentary (when applicable) duties for an assumed symmetrical three-phase bolted fault, bolted line-to-ground fault, and bolted line-to-line fault at each:

1. Electric utility's supply termination point.

2. Main breakers, generator breakers and feeder breakers.

3. Unit substations and medium voltage switchgear.

4. Low voltage switchgear, switchboard and/or distribution panelboard.

5. Motor control centers.

6. Standby generator.

7. Automatic Transfer Switch (if applicable).

8. All branch circuit panelboards.

9. Variable Frequency Drives.

10. Industrial control panels manufactured in accordance with UL 508A and NEC article 409.

11. Other significant locations throughout the system.

12. Future load contributions as shown on one-line diagram.

D. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to short circuit ratings Verify all equipment, main breakers, ATS, and protective devices are applied within their ratings.

2. Adequacy of switchgear, switchboards, motor control centers, unit substations and panelboard bus bar bracing to withstand short-circuit stresses.

3. Adequacy of transformer windings to withstand short-circuit stresses.

4. Cable and busway sizes for ability to withstand short-circuit heating besides normal load currents.

5. Notify Owner in writing, of existing, circuit protective devices improperly rated for the calculated available fault current.

E. Through the General Contractor, furnish expected fault currents for industrial control panels, constructed and installed under other divisions and specifications of this contract, to the panel builder for his coordination with meeting the requirements of UL 508A and NEC article 409.

2.03 PROTECTIVE DEVICE COORDINATION STUDY

A. Proposed protective device coordination time-current curves for distribution system, graphically displayed on log-log scale paper. Time Current Curve plots from SKM CAPTOR™ program are acceptable.

B. Each curve sheet to have title and one-line diagram with legend identifying the specific portion of system associated with time-current curves on that sheet.

C. Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which device is exposed.

D. Identify device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.

E. Perform device coordination on time-current curves for low voltage distribution system(s).

F. Provide Individual protective device time-current characteristics on log-log paper or software generated graphs.

G. Plot Characteristics on Curve Sheets:

1. Electric utility's relays or protective device (if applicable).

2. Electric utility's fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands (if applicable).

3. Medium voltage equipment relays.

4. Medium and low voltage fuses including manufacturer's minimum melt, tolerance, and damage bands.

5. Low voltage equipment circuit breaker trip devices, including manufacturer’s tolerance bands.

6. Transformer full-load current, magnetizing inrush current, and ANSI transformer withstand parameters.

7. Transformer damage curves.

8. Conductor damage curves.

9. ANSI transformer with stand parameters.

10. Significant symmetrical and asymmetrical fault currents.

11. Ground fault protective devices and settings (if applicable).

12. Pertinent motor starting characteristics and motor damage points.

13. Pertinent generator short circuit decrement curve and generator damage point.

14. Circuit breaker panelboard main breakers, where appropriate.

15. Motor circuit protectors for major motors.

H. Provide adequate time margins between device characteristics such that selective operation is provided, while providing proper protection.

I. Primary Protective Device Settings for Delta-Wye Connected Transformer:

1. Secondary Line-to-Ground Fault Protection: Primary protective device operating band within the transformer's characteristics curve, including a point equal to 58 percent of ANSI C57.12.00 withstand point.

2. Secondary Line-To-Line Faults: 16 percent current margin between primary protective device and associated secondary device characteristic curves.

J. Separate medium voltage relay characteristics curves from curves for other devices by at least 0.4-second time margin.

2.04 ARC FLASH ANALYSIS

A. Perform incident energy calculations in accordance with IEEE 1584-2002 Guide for Performing Arc Flash Hazard Calculations for all equipment analyzed in the short circuit study. Tabular results and recommended labels from SKM ARC FLASH™ are acceptable.

B. When appropriate, the short circuit calculations and the clearing times of the phase overcurrent devices will be retrieved from the short-circuit and coordination study model.

C. The flash protection boundary and the incident energy shall be calculated at all significant locations in the electrical distribution system (switchboards, switchgear, motor-control centers, panelboards, bussway and unit substations, variable frequency drives, industrial control panels) where work could be performed on energized parts.

D. The Arc-Flash Hazard Analysis shall include all medium voltage, low voltage and significant locations in 240 volt and 208 volt systems fed from transformers equal to or greater than 125 kVA. Arc-Flash Hazard Analysis on low voltage systems 120V and below is not required.

E. Safe working distances shall be specified for calculated fault locations based upon the calculated arc flash boundary considering an incident energy of 1.2 cal/cm2.

F. The Arc Flash Hazard analysis shall include calculations for maximum and minimum contributions of fault current magnitude. The minimum calculation shall assume that the utility contribution is at a minimum and shall assume a minimum motor load. Conversely, the maximum calculation shall assume a maximum contribution from the utility and shall assume motors to be operating under full-load conditions.

G. Arc flash computation shall include both line and load side of main breaker calculations, where necessary.

H. Arc Flash calculations shall be based on actual overcurrent protective device clearing time. Maximum clearing time will be capped at 2 seconds based on IEEE 1584-2002 Section B.1.2.

I. Furnish recommendations for Personal Protective Equipment, in accordance with OSHA standards, and proper labels to be located on the electrical equipment in accordance with NEC Article 110.16.

J. Use manufacturer data for: enclosure type; gap between exposed conductors or buss way; grounding type; number of phases and connection; and working distance.

2.05 TABULATIONS

A. Input Data:

1. Utility three-phase and line-to-ground available contribution with associated X/R ratios.

2. Short circuit reactances of rotating machines and associated X/R ratios.

3. Cable type, construction, size, quantity per phase, length, impedance and conduit type.

4. Bus data, including impedance.

5. Transformer primary & secondary voltages, winding configurations, kVA rating, impedance, and X/R ratio.

B. Short Circuit Data:

1. Source fault impedance and generator contributions.
2. X to R ratios.
3. Asymmetry factors.
4. Motor contributions.
5. Short circuit kVA.
6. Symmetrical and asymmetrical fault currents.

C. Recommended Protective Device Settings:

1. Phase and ground relays:
    a. Relay name.
    b. Device number.
    c. Description.
    d. TCC catalog number.
    e. Short circuit ratings.
    f. Current transformer ratio.
    g. Current tap.
    h. Time dial setting (as applicable).
    i. Instantaneous pickup setting (as applicable).
    j. Ground fault setting (as applicable).
    k. Specialty, non-overcurrent device settings.
    l. Recommendations on improved relaying systems, if applicable
2. Circuit Breakers:
    a. Breaker name.
    b. Breaker Description.
    c. Model number.
    d. TCC catalog number.
    e. Short circuit rating.
    f. Frame/Sensor rating.
    g. Adjustable pickups and time delays (long time, short time, ground).

h. Adjustable time-current characteristic.

i. Adjustable instantaneous pickup.

j. Recommendations on improved trip systems, if applicable

3. Motor Circuit Protectors (MCP):

a. MCP name.

b. MCP Description.

c. Model number.

d. TCC catalog number.

e. Short circuit rating.

f. Frame/Sensor rating.

g. Instantaneous settings.

4. Fuses:

a. Fuse name.

b. Fuse Description.

c. Model number.

d. TCC catalog number.

e. Short circuit rating.

f. Fuse rating.

D. Incident energy and flash protection boundary calculations.

1. Arcing fault magnitude

2. Device clearing time

3. Duration of arc

4. Arc flash boundary

5. Working distance

6. Incident energy

7. Hazard Risk Category

8. Recommendations for arc flash energy reduction

2.06 STUDY ANALYSES

A. Written Summary:

1. Scope of studies performed.

2. Explanation of bus and branch numbering system.

3. Prevailing conditions.

4. Selected equipment deficiencies.

5. Results of short circuit and coordination studies.

6. Comments or suggestions.

B. Suggest changes and additions to equipment rating and/or characteristics.

C. Notify Engineer in writing of existing circuit protective devices improperly rated for new fault conditions.

PART 3 - EXECUTION

3.01 GENERAL

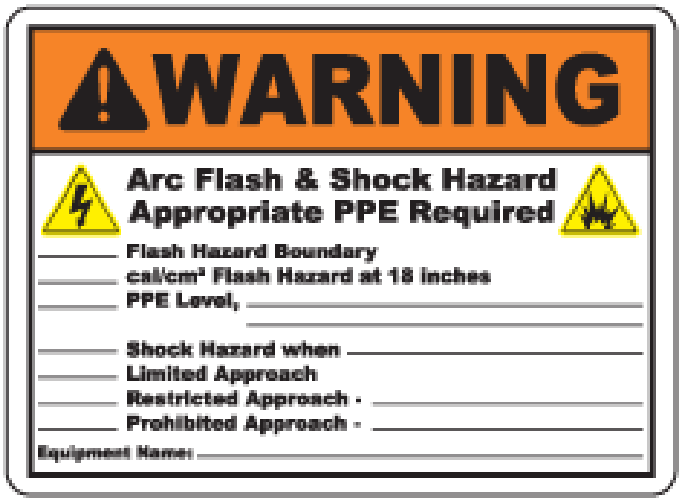
A. Adjust relay and protective device settings according to values established by coordination study.

B. Make minor modifications to equipment as required to accomplish conformance with the short circuit and protective device coordination studies.

C. Notify Engineer in writing of any required major equipment modifications.

3.02 SAMPLE ARC FLASH LABEL

A. Provide and attach all electrical equipment with appropriate Arc Flash label. Arc Flash label shall be weather resistant material and shall match existing Orange County's Standard Arc Flash label, as shown below.



END OF SECTION

SECTION 16050 - BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 - GENERAL

1.01 REQUIREMENT

A. Contractors bidding work under this Contract shall read and understand Division Zero and Division 1 - General Requirements. If any discrepancies are discovered between the Basic Electrical Materials and Methods and General Requirements, the above mentioned documents shall overrule this section. The Basic Electrical Materials and Methods are intended as a supplement to the above mentioned documents.

B. The Contractor shall bid as outlined in the above mentioned Specifications and shall be governed by any alternates or unit prices called for in the form of proposal.

C. Each Contractor bidding on the work included in these Specifications shall view the building site and carefully examine the contract Drawings and Specifications, so that he/she may fully understand what is to be done, and to document existing conditions.

1.02 SCOPE OF WORK

A. Work included in this section of the Specifications shall include the furnishing of all labor, material, tools, approvals, utility connection fees, excavation, backfill, and other equipment necessary to install the electrical system as shown on the Contract Drawings and as specified herein.

B. It also includes installation and connection of all electrical utilization equipment included in this Contract but furnished by other contractors or suppliers.

C. It is the general intent that all motors shall be furnished with the particular object of equipment it drives, except where a new motor is to be provided for an item of existing equipment (a replacement motor), then it shall be provided under this Division of the Specifications.

D. The Contractor shall furnish and install all conduit, wire, disconnect switches and miscellaneous material to make all electrical connections to all items of utilization equipment or wiring devices except as otherwise specified.

E. Equipment connections shall be made with flexible or rigid conduit as required. Controllers for motors, disconnect switches, and all control, protective and signal devices for motor circuits, except where such apparatus is furnished mounted and connected integrally with the motor driven equipment, shall be installed, connected and left in operating condition. The number and size of conductors between motors and control or protective apparatus shall be as required to obtain the operation described in these Specifications, and/or by the Contract Documents, and/or as shown in manufacturer furnished, Engineer reviewed Shop Drawings.

F. All devices and items of electrical equipment, including those shown on the Contract Drawings but not specifically mentioned in the Specifications or those mentioned in the Specifications but not shown on the Contract Drawings, are to be furnished under this section of the specifications. Any such device or item of equipment, if not defined in quality, shall be equal to similar Equipment and/or devices specified herein.

G. All devices and items of equipment mentioned in this section of the Specifications whether electrical or not or whether furnished under this or other Division of the Specifications, shall be installed under this Division of the Specifications, unless specifically indicated otherwise.

H. Where wiring diagrams are not shown on the Contract Drawings, they are to be provided by the supplier of the equipment served and such diagrams shall be adhered to except as herein modified.

I. The following is a list of items that may not be defined clearly on the Contract Drawings or in other parts of these Specifications. The list is meant to be an aid to the Contractor and is not necessarily a complete list of all work to be performed under this Contract:

1. Connect all motors and accessories furnished by equipment suppliers.

2. Furnish, install, and connect all motor controls.

3. Furnish, install, and connect lighting, indoor and outdoor.

4. Furnish, install, and connect power and signal lines to all instrumentation equipment, and accessories.

5. Furnish, install, and connect all electrical conduit, duct and cables.

6. Furnish, install, and connect all telephone boxes, outlets, etc.

7. Furnish, install, and connect all power distribution equipment.

8. Furnish and install standby power equipment.

9. Install all loose ship controls, control panels, instrumentation, cables, sensors, etc. provided by equipment vendors specified under Divisions 11, 13, 15, and 17.

1.03 SHOP DRAWINGS, DESCRIPTIVE LITERATURE, INSTALLATION, OPERATION AND MAINTENANCE INFORMATION

A. Shop Drawings including descriptive literature and/or installation, operation and maintenance instructions shall be submitted per Section 01300.

B. Shop Drawings shall be submitted on the following materials specified in this Division:

1. Conduit - all types and sizes, including liquid-tight flexible.

2. Boxes - all types and sizes.

3. Coal tar epoxy paint.

4. Wiring devices.

5. Device plates.

6. Metal framing system (Strut type channel).

7. Conduit fittings, expansion joints, support hardware.

8. Motor control equipment - including individually mounted items.

9. Power distribution equipment - including individually mounted items.

10. Adjustable speed equipment and accessories.

11. Miscellaneous spare parts and hardware.

12. Wire - all types and sizes.

13. Light fixtures - all types.

14. Wire markers, signs and labels.

15. Lightning/Surge Suppression Devices (SPD's)

16. Motors.

17. Transformers.

18. Standby power equipment and accessories.

C. The Engineer reserves the right to make modifications to motor control and power distribution equipment ratings after Shop Drawing review, if the Shop Drawings are submitted prematurely (prematurely meaning submitted before all utilization equipment has been reviewed and accepted). Cost of modifications shall be the Contractor's responsibility.

1.04 SYMBOLS AND ABBREVIATIONS

A. The symbols and abbreviations general follow standard electrical and architectural practice, however, exceptions to this shall be as shown on the Contract Drawings.

1.05 COORDINATION WITH OTHER TRADES

A. The Contractor shall coordinate the electrical work with that of other trades to ensure proper final location of all electrical equipment and/or connections. The Contractor shall verify door swings to see that light switches are located properly.

1.06 CODES

A. The minimum standard for all work shall be the latest revision of the Kentucky Building Code (KBC), and the National Electrical Code (NEC). Whenever and wherever state and/or local laws or ordinances and/or regulations and/or the Engineer's design require a higher standard that the current NEC or KBC, then these laws and/or regulations and/or the design shall be followed.

B. Following is a list of other applicable Standards or Codes:

1.	Kentucky Building Code	KBC
2.	National Electrical Code	NEC
3.	National Electrical Safety Code	NESC
4.	Underwriters Laboratories, Inc.	UL
5.	Factory Mutual System	FM
6.	National Fire Protection Association	NFPA
7.	National Electrical Manufacturers Association	NEMA
8.	Occupational Safety and Health Administration	OSHA
9.	Insulated Cable Engineers Association, Inc.	ICEA
10.	Illuminating Engineering Society of North America	IES
11.	Instrument Society of America	ISA

12.	Institute of Electrical and Electronic Engineers, Inc.	IEEE
13.	Certified Ballast Manufacturers Association	CBM
14.	American National Standards Institute, Inc.	ANSI
15.	Anti-Friction Bearing Manufacturers Association, Inc.	AFBMA
16.	Joint Industry Council	JIC
17.	American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.	ASHRAE
18.	Federal Communications Commission	FCC
19.	American Society for Testing and Materials	ASTM
20.	American Wood Preservers Association	AWPA
21.	Rural Electrification Association	REA

1.07 INSPECTIONS AND PERMITS

A. Inspection of the electrical system on all construction projects is required. If the local government has appointed a state licensed inspector, the Contractor shall be required to use that person to perform the inspections. If a locally mandated inspector does not exist, the Contractor shall select and hire a state licensed inspector, who has jurisdiction before any work is concealed. The Contractor shall notify the electrical inspector in writing, immediately upon notice to proceed, and a copy of the notice shall be submitted to the Engineer.

B. At the time of completion of the project, there shall be furnished to the Owner a certificate of compliance, from the agency having jurisdiction pursuant to all electrical work performed. The Engineer shall also receive a photostatic copy.

C. All costs incurred by the Contractor to execute the above mentioned requirements shall be paid by the Contractor at no extra cost to the Owner.

D. All permits necessary for the complete electrical system shall be obtained by the Contractor from the authorities governing such work. For further information, see Division 1.

1.08 STORAGE

A. All work, equipment, and materials shall be protected against dirt, water, or other injury during the period of construction.

B. Sensitive electrical equipment such as light fixtures, motor starters, controls, and panelboards, delivered to the job site, shall be protected against injury or corrosion due to atmospheric conditions or physical damage by other means. Protection is interpreted to mean that equipment shall be stored under roof, in a structure properly heated in cold weather and ventilated in hot weather. Provision shall be made to control the humidity in the storage area to 50 percent relative. The stored equipment shall be inspected periodically, and if it is found that the protection is inadequate, further protective measures shall be employed. Electrical equipment other than boxes and conduit shall not be installed until the structure is under roof with doors and windows installed.

C. No light fixtures or device plates shall be hung or installed until after painting is completed; however, temporary lighting shall be provided by the Contractor.

D. The Contractor shall not store submersible pump units in the wetwell. If it is absolutely necessary to do so, the open power cable ends are to be suspended above the maximum flood elevation or maximum expected water level. If not stored in this manner, the Contractor may be called upon to replace the pump motors and cables with new units to ensure that water has not penetrated the cable and entered the motor housing.

1.09 MATERIALS

A. All materials used shall be new and at least meet the minimum standards as established by the NEC and/or National Electrical Manufacturers Association (NEMA). All materials shall be UL listed for the application, where a listing exists. Additional requirements are found in Division 1. All equipment shall meet applicable FCC requirements and restrictions.

B. The material and equipment described herein has been specified according to a particular trade name or make to set quality standards. However, each Contractor has the right to substitute other material and equipment in lieu of that specified, other than those specifically mentioned at matching or for standardization, providing such material and equipment meets all of the requirements of those specified and is accepted, in writing by the Engineer.

C. The reuse of salvaged electrical equipment and/or wiring will not be permitted unless specified herein or indicated on the Contract Drawings.

D. All salvaged or abandoned electrical materials shall become the property of the Contractor and shall be removed from the job site upon completion of the project, unless otherwise noted on the Contract Drawings or specified herein.

1.10 ERRORS, CORRECTIONS, AND/OR OMISSIONS

A. Should a piece of utilization equipment be supplied of a different size or horsepower than shown on the Contract Drawings, the Contractor shall be responsible for installing the proper size wiring, conduit, starters, circuit breakers, etc., for proper operation of that unit and the complete electrical system at no extra cost to the Owner.

B. It is the intent of these Specifications to provide for an electrical system installation complete in every respect, to operate in the manner and under conditions as shown in these Specifications and on the Contract Drawings. When drawings and plans conflict and there is insufficient time to request clarification for bids, contractor shall follow the specifications for bid purposes and if awarded the contract shall initiate an RFI for further clarification prior to construction. Further requirements on this subject may be found in the General Requirements, Division 1.

C. Necessary changes or revisions in electrical work to meet any code or power company requirement shall be made by the Contractor without additional charge.

1.11 GUARANTEES AND WARRANTIES

A. The Contractor shall guarantee all work including equipment, materials, and workmanship. This guarantee shall be against all defects of any of the above and shall run for a period of 1 year from the date of acceptance of the work, concurrent with the one year guarantee period designated for the general construction contract under which electrical work is performed. Date of acceptance shall be considered to be the date on which all “punch list” items are completed (“punch list” is defined to be the written listing of work that is incomplete or deficient that must be finished or replaced/repaired before the Contractor receives final payment).

B. Repair and maintenance for the guarantee period is the responsibility of the Contractor and shall include all repairs and maintenance other than that which is considered as routine. (That is oiling, greasing, etc.) The Engineer shall be the judge of what shall be considered as routine maintenance.

C. Lamps shall bear the manufacturer's warranty.

1.12 TESTING

A. After the wiring system is complete, and at such time as the Engineer may direct, the Contractor shall conduct an operating test for acceptance. The equipment shall be demonstrated to operate in accordance with the requirements of these Specifications and the Contract Drawings. The test shall be performed in the presence of the Engineer or his authorized representative. The Contractor shall furnish all instruments and personnel required for the tests, as well as the necessary electrical power.

B. Before energizing the system, the Contractor shall check all connections and set all relays and instruments for proper operation. He shall obtain all necessary clearances, approvals, and instructions from the serving utility company and/or equipment manufacturers prior to placing power on the equipment.

C. Tests may be performed by the Engineer to determine integrity of insulation on wiring circuits selected by the Engineer at random.

D. Cost of utilities for testing done prior to beneficial occupancy by the Owner shall be borne by the Contractor.

1.13 CLEANUP

A. Cleanup shall be completed as soon as possible after the electrical installation is complete. All light fixtures, outlets, switches, starters, motor control centers, disconnect switches and other electrical equipment shall be free of shipping tags, stickers, etc. All painted equipment shall be left free of scratches or other blemishes, such as splattered or blistered paint, etc. All light fixture diffusers shall be clean and the interior of all motor controls, etc., shall be free of dust, dirt, wire strippings, etc. Surplus material, rubbish and equipment resulting from the work shall be removed from the job site by the Contractor upon completion of the work.

B. During construction, cover all Owner equipment and furnishings subject to mechanical damage or contamination in any way.

1.14 CUTTING AND PATCHING

A. Cutting and patching shall be held to an absolute minimum and such work shall be done only under the direction of the Engineer or Owner. The Contractor shall be responsible for and shall pay for all openings that may be required in the floors or walls, and he shall be responsible for putting said surfaces back in their original condition. Every attempt shall be made to avoid cutting reinforcing steel bars when an opening is required in a reinforced concrete wall or floor slab.

1.15 EXCAVATION AND BACKFILL

A. Excavation

1. Excavation for conduits shall be of sufficient width to allow for proper jointing and alignment of the type conduit used. Conduit shall be laid in straight lines between pull boxes and/or structures unless otherwise notes on the Contract Drawings. The cost of solid rock excavation shall be included in the lump sum bid with no extra pay allowed (unclassified).

B. Encasement/Backfill

1. All buried conduits shall be concrete encased. Backfill over the ductbank may contain rocks but must be mixed with sufficient earth to fill all voids.

1.16 SLEEVES, CHASES AND OPENINGS

A. Sleeves shall be required at all points where exposed conduits pass through new concrete walls, slabs, or masonry walls. Sleeves that must be installed below grade or where subject to high water conditions must be installed watertight.

B. Wiring chases shall be provided where shown on the Contract Drawings. The Contractor shall have the option of installing chases below surface mounted panelboards provided all structural requirements are met.

C. It is the Contractor's responsibility to leave openings to allow installation of the complete, operational electrical system. Openings required but not left shall be cut as outlined under cutting and patching. The Contractor shall coordinate all holes and other openings with necessary diameters for proper firestopping.

1.17 POWER COMPANY COORDINATION

A. The Contractor is responsible for coordinating all activities onsite by the power company.

B. All power company metering equipment shall be electrically located "upstream" of any manual/automatic transfer equipment on projects requiring onsite emergency power generation equipment.

C. Any special provisions required by the serving electrical utility shall be as outlined on the Contract Drawings or as advised by the utility at the time of construction, and work required by these special provisions shall be executed with no extra cost to the Owner.

1.18 TEMPORARY ELECTRICAL POWER

A. The Contractor shall be responsible for providing temporary electrical power as required during the course of construction and shall remove the temporary service equipment when no longer required. Temporary power is also addressed in Division 1.

1.19 OVERCURRENT PROTECTION

A. Circuit breakers or fused switches shall be the size and type as written herein and shown on the Contract Drawings. Any additional overcurrent protection required to maintain an equipment listing by an authority having jurisdiction shall be installed by the Contractor at no extra cost to the Owner.

B. The Contractor shall submit to the Engineer actual nameplate data from motors shipped to the site, stating motor identification as well as characteristics. Overload relay thermal unit selection tables shall accompany the motor data. The Engineer will select thermal unit sizes from this data for use by the Contractor in ordering proper thermal units.

1.20 TRAINING

A. All manufacturers supplying equipment for this division shall provide the Owner's operations staff with training in the operation and maintenance on the equipment being furnished. The training shall be conducted at the project site by a qualified representative of the manufacturer.

B. The cost of this training shall be included in the bid price.

C. The required training shall consist of both classroom and hands-on situation. Classroom training shall include instruction on how the equipment works, its relationship to all accessories and other related units, detailed review of shop drawings, detailed presentation of written O & M instructions, troubleshooting and record-keeping recommendations. Hands-

on-training shall include a review of the manufacturer's O & M instructions, check out of each operator to identifying key elements of the equipment, tear down as appropriate, calibration, adjustment, greasing and oiling points, and operating manipulations of all electrical and mechanical controls.

D. The training shall be scheduled through the Contractor with the Owner. The timing of the training shall closely coincide with startup of the equipment, but no training shall be conducted until the equipment is operational.

E. The minimum number of hours to be provided by manufacturers supplying equipment on this project shall be in accordance with the following table:

	Training Hours	
Item	Classroom	Hands-on
Standby Power System & Accessories	2	2
Variable Speed Systems	2	2
Automatic Level/Pressure Control System	1	1

F. At least 60 days prior to the training the manufacturer shall submit through the Contractor to the Engineer an outline of the training proposed for the Engineer's review and concurrence.

G. The Owner reserves the right to videotape all training sessions.

1.21 MAINTAINING CONTINUOUS ELECTRICAL SYSTEM AND SERVICE

A. Existing service(s) continuity shall be maintained at all times. In no way shall the installation and/or alteration of the electrical work interfere with or stop the normal operation of the existing facilities, except where prior arrangements have been made

B. When additions and taps to existing service(s) require electrical outages of duration in excess of a few minutes, arrangements shall be made in advance for such outages. All outages shall be held to an acceptable minimum with none exceeding 8 hours continuous duration. If necessary, cuts shall be performed on premium time. If performed at night, requiring a general outage, the Contractor shall furnish an auxiliary source of light and power as required. Under no circumstances shall an electrical outage of any duration be initiated until the Owner and Engineer have concurred, and as far as possible in advance.

C. See Section 01520 for additional requirements.

1.22 GROUNDING AND BONDING

A. All metallic conduit, cabinets, equipment, and service shall be grounded in accordance with the latest issue of the National Electrical Code. All supporting framework and other metal or metal clad equipment or materials which are in contact with electrical conduit, cable and/or enclosures, shall be properly grounded to meet the code requirements.

1.23 RELATED SPECIFICATION DIVISIONS

A. The following divisions contain Specifications on utilization equipment, equipment accessories, and procedures related to execution of the electrical work, and are included here for the Contractor's information. Bids shall still be based on complete Contract Documents.

Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract
Division 1 - General Requirements
Division 11 - Equipment
Division 13 - Special Construction

Division 15 – Mechanical
Division 17 - Instrumentation

1.24 SERVICE ENTRANCE

A. Conductors and terminations for service entrances shall be furnished and installed by the Contractor. Voltage, phase, and number of wires shall be as shown on the Drawings. Clearances for overhead entrance wires shall be per serving Electric Utility Requirements, NEC, and NESC requirements.

B. Any details not shown on the Drawings or written in the Specifications pertaining to the service entrance shall be per serving Electric Utility requirements. It is the Contractor's responsibility to contact the utility prior to bidding and obtain any special requirements or costs they will be imposing. Those costs shall be included in the bid.

C. On underground service entrances from pad mounted transformers, the Contractor shall be responsible for furnishing and installing all primary, secondary, and metering conduits, as well as secondary service/metering conductors. The Contractor shall be responsible for furnishing pull wires in primary conduits for use by the power company. The Contractor shall be responsible for fabricating the required concrete pad that the transformer will be mounted on. The Contractor shall also mount the meter base furnished by the power company.

1.25 CONTRACTOR LICENSING

A. The Contractor performing the electrical work on this project shall be locally licensed, if required by local law or ordinance. If the Contractor has passed the State test, it may not be necessary to meet local testing requirements. It shall be the Contractor's responsibility to investigate these requirements and comply with same.

1.26 ANCHORING/MOUNTING

A. Electrical conduits and/or equipment shall be rigidly supported. Anchors used shall be metallic expansion type, or if appropriate to prevent spalling concrete, epoxy set type. Plastic or explosive type anchors are prohibited.

B. All supports shall be consistent with the latest edition of the KBC and ASCE 7.

1.27 ELECTRICAL COMPONENT MOUNTING HEIGHTS

A. Unless otherwise indicated, mounting height for components shall be as defined herein. In cases of conflicts with architectural or structural aspects, the components may be relocated. If an indicated height conflicts with a code requirement, the code shall govern.

B. Mounting heights are given from finished floor elevation to the centerline of the component, unless otherwise noted.

	Component	Height	Comments
1.	Wall type light switch	4'-0"	To top of box
2.	Low wall outlet	16"	To bottom
3.	Medium height wall outlet	4'-0"	
4.	Medium height telephone outlet	4'-0"	
5.	High wall outlet or fixture	7'-0"	
6.	Wall type buzzers, horns, etc.	8'-0" Max.	Top 2" below ceiling
7.	Push-button or control stations	4'-0"	
8.	Top of panelboards or control panels	6'-6"	Maximum (except for handicapped areas)
9.	Top of telephone back boards	6'-6"	Maximum
10.	Top of switch handle on motor control center	6'-6"	Maximum

11.	Top of local motor controller	6'-0"	Maximum
12.	Top of local disconnect switch	6'-0"	Maximum
13.	Wall mount exterior light fixtures	8'-0"	or as shown
14.	Wall mount emergency light fixtures	6'-6"	Maximum to test button
15.	Wall thermostats	4'-0"	To top of thermostat

In situations where there appears to be a conflict with Americans with Disabilities Act (ADA) legislation, utilize the ADA requirements herein.

1.28 HAZARDOUS AREA CLASSIFICATIONS

The following table identifies the applicable hazardous areas for this project, and the classifications for each. All equipment used in these areas shall be UL listed for the application, and all wiring methods shall be in accordance with Chapter 5 of the National Electrical Code. All conduits to these spaces from non-hazardous areas shall be properly sealed.

Location	**Area Classification**	**Extent of Hazardous Area**
Wetwell	Class I, Division 1, Group D	Entire Wetwell
Valve Vault	Class I, Division 2, Group D	Entire Vault
Diversion Structure/ Screenings Area	Class I, Division 1, Group D	Entire Structure
Meter Vaults	Class I, Division 2, Group D	Entire Vault
Wet Weather Storage (covered)	Class I, Division 1, Group D	Entire Structure
Electrical Building	Unclassified	Entire Building

Note: These ratings are based on no continuous ventilation and some may be rerated if continuous ventilation is provided (per NFPA 820).

1.29 RECEIPTS

A. Some sections of the Specifications call for equipment, materials, accessories, etc. to be provided and “turned over to the Owner” or like requirements. The Contractor shall obtain a receipt for each item turned over, signed by the Owner or his representative. A copy of this receipt shall be transmitted to the Engineer.

B. When a question arises concerning whether items have been turned over to the Owner, and there is no signed receipt, it may be assumed that the items were not provided.

1.30 POWER SYSTEM STUDIES

A. General

1. The Contractor shall provide Short Circuit Studies, Protective Device Evaluation Studies, Protective Device Coordination Studies, and Arc Flash Studies performed by a professional registered electrical engineer currently registered in the State of Kentucky for the entire electrical system. The studies shall be performed in accordance with 399-1997, IEEE Recommended Practice for Industrial and Commercial System Power Analysis (IEEE Brown Book). The studies shall be submitted to the Engineer prior to receiving final approval of the distribution equipment shop drawings and/or prior to release of equipment for manufacture. If formal completion of the studies may cause delay in equipment manufacture, approval from the Engineer may be obtained for a preliminary submittal of sufficient study data to insure that the selection of device ratings and characteristics will be satisfactory.

2. The studies shall include all portions of the electrical distribution system from the utility company protective devices, the normal and standby power sources down to and including the 480 volt feeder protective devices for each feeder. The study shall include all low and medium voltage switchgear, MCCs, and panelboards. System connections and those which result in maximum fault conditions shall be adequately covered in the study.

3. In the event that the short circuit study requires a higher interrupting and/or withstand rating of equipment than that which is indicated in the Contract Documents, the Contractor shall furnish and install the equipment as required based on the study with no extra cost to the Owner.

4. In the event that the protective device coordination study indicates that different settings or equipment is required than that which is specified, the Contractor shall furnish and install the equipment based on the study with no extra cost to the Owner.

B. Data Collection for the Studies

1. The Contractor shall provide the required data for preparation of the studies. The preparer of the studies shall furnish the Contractor with a listing of the required data immediately after award of the Contract.

2. The Contractor shall expedite collection of the data to assure completion of the studies as required for final approval of the distribution equipment shop drawings and/or prior to release of the equipment for manufacture.

C. Short Circuit Study and Protective Device Evaluation Study

1. The short circuit study shall be performed with the aid of a digital computer program and shall be in accordance with the latest editions of IEEE Std. 399 and IEEE Std. 141.
2. The study input data shall include the utility company's short circuit contribution, resistance and reactance components of the branch impedances, the X/R ratios, base quantities selected, and other source impedances.

3. Short circuit close and latch duty values and interrupting duty values shall be calculated on the basis of assumed three-phase bolted short circuits at each bus, switchgear, medium and low-voltage motor control center, distribution panelboard, pertinent branch circuit panel and other significant locations through the system. The short circuit tabulations shall include symmetrical fault currents, and X/R ratios. For each fault location, the total duty on the bus, as well as the individual contribution from each connected branch, shall be listed with its respective X/R ratio.

4. A protective device evaluation study shall be performed to determine the adequacy of circuit breakers, molded case switches, automatic transfer switches, and fuses by tabulating and comparing the short circuit ratings of these devices with the calculated fault currents. Appropriate multiplying factors based on system X/R ratios and protective device rating standards shall be applied. Any problem areas or inadequacies in the equipment due to short circuit currents shall be promptly brought to the attention of the Engineer.

5. All equipment furnished shall meet the requirements of this study, with no extra cost to the Owner.

D. Protective Device Coordination Study

1. A protective device coordination study shall be performed to provide the necessary calculations and logic decisions required to select or to check the selection of power fuse ratings, protective relay characteristics and settings, ratios and characteristics of

associated current transformers, and low voltage circuit breaker trip characteristics and settings.

2. The coordination study shall include all low voltage classes of equipment from the utility company service protective devices down to and including the main circuit breakers of motor control centers. The phase and ground overcurrent protection shall be included as well as settings of all other adjustable protective devices.

3. The time-current characteristics of the specified protective devices shall be drawn on log-log paper. The plots shall include complete titles, representative one-line diagram and legends, significant motor starting characteristics, complete parameters of transformers, complete operating bands of low voltage circuit breaker trip curves and fuses. The coordination plots shall indicate the types of protective devices selected, proposed relay taps, time dial and instantaneous trip settings, transformer magnetizing inrush and ANSI transformer withstand parameters, cable thermal overcurrent withstand limits and significant symmetrical and asymmetrical fault currents. All restrictions of the National Electrical Code shall be adhered to and proper coordination intervals and separation of characteristic curves shall be maintained. The coordination plots for phase and ground protective devices shall be provided on a system basis. A sufficient number of separate curves shall be used to clearly indicate the coordination achieved.

4. The selection and settings of the protective devices shall be provided separately in a tabulated form listing circuit identification, IEEE device number, current transformer ratios and connections, manufacturer and type, range of adjustment and recommended settings. A tabulation of the recommended power fuse selection shall be provided for the medium voltage fuses where applied in the system. Any discrepancies, problem areas, or inadequacies shall be promptly brought to the attention of the Engineer.

E. Arc Flash Hazard Analysis

1. An Arc Flash Hazard Analysis shall be performed with the aid of a digital computer program in accordance with IEEE Std. 1584, “IEEE Guide For Performing Arc Flash Hazard Calculations”, NFPA 70E, and OSHA 29-CFR, Part 1910 Subpart S.

2. Arc Flash Warning Labels and Bus Detail Sheets shall be produced for each bus. Labels shall be printed in color on vinyl U.V. rated adhesive backed labels. Labels shall be attached to the doors of the equipment. Each label and detail sheet shall list the following:

   a. Bus name

   b. System operating voltage

   c. Date of issue

   d. Flash hazard protection boundary

   e. Limited approach boundary

   f. Restricted boundary

   g. Prohibited boundary

   h. Incident energy level

   i. Required personal protective equipment class

   In addition, each Bus Detail Sheet shall list the following:

1). Upstream Protective Devices Names, Type and Settings

3. Arc Flash Evaluation Summary Sheets shall be produced. Summary sheets shall list the following:

   a. Bus name

   b. Upstream protective device name, type and settings

   c. Bus line-to-line voltage

   d. Bus bolted fault

   e. Protective device bolted fault current

   f. Arcing fault current

   g. Protective device trip / delay time

   h. Breaker opening time

   i. Solidly grounded column

   j. Equipment type

   k. Gap

   l. Arc flash boundary

   m. Working distance

   n. Incident energy

   o. Required personal protective equipment class

4. Analyze the short circuit, protective device coordination, and arc flash calculations and highlight any equipment that is determined to be underrated or causes an abnormally high incident energy calculation. Propose approaches to reduce the energy levels. Proposed major corrective modifications will be taken under advisement by the Engineer and the Contractor will be given further instructions.

F. Study Report

1. The results of the power system studies shall be summarized in a report. The report shall be submitted to the Engineer. The report shall be submitted for review and acceptance prior to submittals for medium voltage switchgear, medium voltage motor control equipment, low voltage switchgear and switchboards, motor control centers, variable frequency drives, panelboards, and similar electrical equipment.

2. The report shall include the following sections:

   a. Description, purpose, basis and scope of the study and a detailed single line diagram with "nodes" cross-referenced to the calculated values tabulated in the study report of that portion of the power system which is included within the scope of the study.

   b. Tabulations of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties and commentary regarding same.

   c. Protective device time versus current coordination curves, tabulations of relay and

circuit breaker trip settings, fuse selection, and commentary regarding same.

d. Fault current calculations including a definition of terms and guide for interpretation of computer printout.

3. Prior to commencing the work, the preparer the studies shall meet with the testing firm that will do the relay field testing and the Owner's representative at the site for a walk through of the facility to insure that existing conditions are taken into account.

4. The study shall include a detailed explanation of all software programs and procedures used to arrive at the calculated values, settings, and drawings (e.g. single line diagrams) showing fault valves at all busses.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION (NOT USED)

END OF SECTION

SECTION 16060 - SECONDARY GROUNDING

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Grounding shall be done in accordance with the NEC, as described in these Specifications, and as shown on the Contract Documents.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Grounding equipment shall be Cadweld, T&B Blackburn, ITT Weaver, Copperweld Bimetallics Group, or equal.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Grounding shall utilize a supplemental driven ground rod system in a bed to achieve the design ground resistance.

B. The ground system shall be continuous with all structures on a common ground. This can be accomplished by bonding all conduits together and bonding to the ground bus at each motor control center. Bonding jumpers shall be required at all pull boxes, and at all motor casings. A separate grounding conductor shall be pulled in all conduits in addition to wire counts shown on Drawings.

C. Ground rods shall be 3/4" x 10'-0" copper clad type. Where multiple rods are driven, they shall be separated by at least 10 feet to assure maximum effect.

D. Ground resistance between ground and absolute earth shall not exceed 5 ohms.

E. All grounding and grounding electrode systems shall be as required by the NEC as for types of electrodes utilized and sizing of grounding conductor to service equipment from the electrode system. These shall include footer rebar, buried metal water pipe, buried bare copper conductor, etc.

F. All grounding electrode system connections shall be made using exothermic welds, Cadweld, or equal. No splices are allowed in the grounding electrode conductor.

G. An insulated, isolated ground shall be run from the service entrance to panels serving computers.

H. Should ground rods be impractical for use due to rocky conditions, then grounding electrode plates may be used after acceptance by the Engineer on a case by case basis.

3.02 FIELD QUALITY CONTROL

A. Testing

1. The Contractor shall be required to provide all labor, tools, instruments, and materials as necessary to perform testing of the grounding electrode system. Results shall be submitted in writing to the Engineer. The testing shall be done to determine the effectiveness of the selected grounding scheme and to see that it conforms with resistance specified (5 ohms maximum).

2. The testing should be done using a fall-of-potential method test at the point of grounding electrode conductor connection to main power distribution equipment and at each separately derived system or MCC. The test shall be performed no sooner than 48 hours after a rainfall event and witnessed by the Owner's designated representative.

3. The written report should contain the following information:

   a. Type of ground scheme used, i.e., building steel, driven rod, mat, etc.

   b. Type of instrument used.

      1) Manufacturer

      2) Model Number

      3) Confirm fall-of-potential test

      4)* Serial Number

      5)* Where instrument was obtained

      6) Calibration Date for instrument used.

         * These 2 items are required so that the same instrument may be utilized should reproduction of the test be necessary due to unsatisfactory readings/instrument miscalibration.

   c. Ground resistance readings obtained at various test distances.

   d. Ground resistance/distance curve.

   e. Value of Grounding Electrode Resistance at knee of curve.

   f. Sketch showing setup of instrumentation and location of grounding electrode and test probes.

   g. Proposed method to achieve the specified resistance, should an unacceptable reading be obtained.

   h. Ground resistance readings obtained (if applicable) after modifications incorporated.

END OF SECTION

SECTION 16070 - SUPPORTING DEVICES

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. All electric equipment shall be rigidly mounted, and installed using supporting devices as indicated on the Contract Drawings, as required by the work, and described herein.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Kindorf,” “Unistrut,” or equal.

2.02 MATERIALS

A. All mounting brackets and strut shall be aluminum. Fasteners, including nuts, bolts, washers and all associated hardware, used to mount equipment shall be stainless steel.

B. Aluminum support members shall not be installed in direct contact with concrete. Stainless steel or non-metallic "spacers" shall be used to prevent contact of aluminum with concrete.

PART 3 - EXECUTION

3.01 ANCHORING CABINETRY

A. All free standing equipment shall be anchored to its foundation using expansion bolts of the size and number recommended by the equipment manufacturer.

3.02 SEISMIC CONSIDERATIONS

A. Where indicated, seismic restraints shall be provided for electrical equipment.

END OF SECTION

SECTION 16075 - ELECTRICAL IDENTIFICATION

PART 1 - GENERAL

1.01 EQUIPMENT LABELING

A. All starters, feeder units in panelboards, switchboards, disconnects, instruments, etc. shall be marked to indicate the motor, outlet, circuit they control, or variable monitored. Marking is to be done with engraved laminated nameplates and shall bear the designation shown on the Contract Drawings where this information is given. Nameplates shall be fastened to equipment with stainless steel screws, minimum of one each side. In no way shall the installation of mounting screws void the NEMA enclosure rating of the equipment in which they are installed. If there are more than one identical unit, they shall be given consecutive numbers or other descriptions as designated by the Engineer. Nameplate background color shall be white, with black engraved letters, unless otherwise noted.

B. Branch circuits in lighting panels shall be typed on a card suitable for the card frame furnished with the panel. The card shall bear the panel designation listed on the Contract Drawings where this information is given, as well as indicate what each circuit controls.

C. Motor control centers, individual wall mounted starters, panelboards, and disconnect switch shall be labeled with vinyl self-adhesive signs that warn of “High Voltage” (state the specific voltage). Main service entrance conduits to a building, where exposed, shall be labeled with the voltage of the service they carry. Other major equipment such as transformers, transfer switches, generator sets, pump control panels, etc., shall be labeled as such. The type of labels to be used shall have orange as the basic color to conform with OSHA requirements, letters shall be black. The labels shall be of proper size to fit flatly on the surface of the enclosure to make for a neat appearance and not interfere with the operating function of the device it is attached to. These labels shall be as manufactured by the Brady Identification Systems Division, Safety Sign Company, or equal.

D. Furnish and install “Authorized Personnel Only” signs by doors into all power distribution equipment rooms/buildings. Furnish and install other signs as indicated on the Contract Drawings.

PART 2 - PRODUCTS (NOT USED)

PART 3 – EXECUTION (NOT USED)

END OF SECTION

SECTION 16120 - CONDUCTORS AND CABLES

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. All wire and cable shall conform to the latest requirements of the NEC and shall meet all ASTM/UL specifications. Wire and cable shall be new; shall have size, grade of insulation, voltage rating and manufacturer's name permanently marked on the outer covering at regular intervals. Complete descriptive literature shall be submitted to the Engineer for review and acceptance prior to installation.

B. Building wire #12 - #1 shall be applied based on a 60 degree Celsius temperature rise. Building wire larger than #1 may be applied at its 75 degree Celsius temperature rise.

1.02 DELIVERY, STORAGE AND HANDLING

A. Wire and cable shall be suitably protected from weather and damage during storage and handling and shall be in first class condition when installed.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Building Wire (types "THWN" and "THW"-cu.) – "Southwire," "Collyer," "American," "Carol," or equal.

B. Control Cables (Shielded or unshielded) 600V max. – "Belden," "Eaton-Dekoron," "Okonite," or equal.

C. Instrumentation Cables (Shielded) 600V mx. – "Eaton-Dekoron," "Manhatton," "American," "Belden," "Okonite," or equal.

2.02 MATERIALS

A. General

1. In general, all conductors shall be 98 percent conductive, annealed copper unless otherwise noted on the Contract Drawings.

2. Conductors shall be type THW or THWN insulation. Conductor size shall be AWG (American Wire Gauge) Standard. Minimum conductor size shall be AWG number 12 except branch circuits in excess of 75 feet from panel to first outlet not smaller than no. 10 AWG. Minimum voltage rating shall be 600 volts. Conductors for small power may be solid (i.e. lighting, receptacles), but conductors for control work shall be stranded.

3. Conductors with high temperature rated insulations and special construction shall be used where required in connecting to light fixtures or appliances that have special requirements.

B. VFD Cable

1. The cable shall be 600V/1000V rated, with stranded tinned copper conductors, shielded, suitable for use with Variable Frequency Drives.

2. The insulation shall be rated for 90 degrees Celsius Wet/Dry operating temperature.

3. Accessories (terminations) shall have ratings that are at least equal to those of the cable.

4. All cables shall be round.

5. Cable shall be suitable for use in wet/dry locations, indoors and outdoors, in cable trays, in conduits, trenches, and in underground ducts and direct burial.

6. The conductor shall be annealed stranded tinned copper per ASTM B3, B8, and B33.

7. The insulation thickness shall have a minimum average wall thickness of 30 mils. The insulation material must be XLPE with an XHHW-2 listing per UL 44. Each insulated conductor shall be identified in accordance with ICEA Method 4 color coding.

8. The insulated conductors are to be cabled together with a minimum of one ground wire. The ground wire(s) are to have a minimum circular mil area equivalent to one circuit conductor. Fillers shall be included as necessary to make the cable round.

9. The cabled assembly shall be shielded using one of two methods:

    a. Applying helically two 2-mil copper tapes. The shield shall provide 100% coverage over the assembly.

    b. Applying an 80% minimum coverage tinned copper braid shield used in conjunction with an Aluminum Foil shield tape.

10. All cables shall have a continuous overall outer sheath of Polyvinyl Chloride (PVC), suitable for 90 degree Celsius use.

11. The jacket shall be resistant to abrasion, rated for direct burial, sunlight resistant, and flame resistant in accordance with UL 1277.

12. The following permanent legend shall be clearly embossed or printed at approximately 2 foot intervals on the outer jacket for the entire length of the cable:

    a. Manufacturer's name and or Trade Mark.

    b. Number of conductors and size (-- AWG).

    c. Type of insulation (XLPE) or NEC Listed Conductor Type (XHHW-2).

    d. Voltage rating.

    e. TC-ER rating.

    f. 1000V Flexible Motor Supply Cable rating.

    g. Sequential footing marking at 2 foot intervals.

13. Only one continuous (without splices) length of cable shall be shipped on a reel. Both ends shall be waterproof sealed, secured, protected from damage, and both ends shall be available for testing.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. General

1. Conductors shall be continuous from outlet to outlet and no splices shall be made except accessible in junction or outlet boxes. Wire connectors of insulating material or solderless pressure connectors, properly taped, shall be used for all splices in wiring, wherever possible.

2. Conductors shall be color coded in accordance with the following schedule:

	480/277V 3 Phase	208/240V 3 Phase	120/240, Single Phase
Phase A	Brown	Black	Black
Phase B	Orange	Red	Red
Phase C	Yellow	Blue	
Neutral (Grounded)	White or Light Gray	White or Light Gray	White or Light Gray
3-Way Tracers			Blue
Grounding	Green	Green	Green
Remote Energized Conductors (Control)			Yellow
Control	Std. Code	Std. Code	

3. Conductors shall be pulled into raceways in strict accordance with manufacturer's recommendations.

4. Ample slack conductors shall be allowed at each terminal point, and pull or junction box, to permit installation with ease and without crowding.

5. All conductors terminating at terminal blocks shall be identified with numbers and/or letters identical to circuit or control identification.

6. No conductors shall be drawn into conduits until all work which may cause wire or cable damage is completed. Wire pulling shall be accomplished utilizing machinery and accessories intended for the purpose.

7. All connections and splices shall be made in accordance with conductor manufacturer's recommendations, and as written herein.

8. In general, feeder sizes shown are based on no more than three current carrying conductors in a conduit. Multiple small branch circuit feeders may be combined in a common conduit, provided conductors are derated in accordance with NEC article 310-15.

9. Unless otherwise specifically indicated, neutrals may not be shared.

B. Feeders

1. All feeders are of the secondary type, below 600 volts, unless otherwise noted. Secondary feeder voltage shall be 480 volt, as noted in the Contract Drawings. Three phase, 4 wire for power and 208/120 volt, 3 phase, 4 wire for general lighting, unless otherwise noted. The Contractor shall furnish and install all feeders from the distribution center(s) to each of the other structures/subpanels as shown on the Contract Drawings.

2. Wire shall be factory color coded for each phase and neutral, with green used for the ground conductor. As far as practical, all feeders shall be continuous from origin to panel termination without running splices in intermediate pull boxes.

C. Control Cable

1. Control cable shall be the size and have the number of conductors shown on the control system drawings. Control cable shall be used for motor controls and monitoring only. Color coding shall be ICEA, Method 1. Control cables between buildings shall be underground in conduit of the size shown in the control system schematic. Cabling shall provide a minimum of 25 percent spare conductors. Voltage rating shall be 600 volts.

D. Instrument Cable

1. General

a. All signal lines should be constructed of individually twisted pairs (6 to 10 twists per foot), including thermocouple extension leads. Cables should be made of twisted pairs, with all lays and pairs twisted in the same direction for maximum flexibility.

b. Wire size is #16 AWG minimum.

c. Stranded tinned copper conductor shall be used for all wiring other than thermocouple extension leads.

d. Insulation resistance at 68 degrees Fahrenheit between conductors and between conductors and ground should be at least 500 megohms per 1,000 feet.

e. Multi-pair cable should be jacketed with poly-vinyl-chloride, polyethylene or Teflon at least 0.045" thick. Voltage rating shall be 600 volts.

2. Signal Wiring

a. Low level analog (less than 500 millivolt d-c). Use twisted pairs which may be cabled with other pairs carrying similar voltage levels. Foil wraps or equivalent shielding is required for each cable with the shield insulated from ground.

b. High level analog (greater than 500 millivolts d-c). Use twisted pairs which may be cabled with other pairs carrying similar voltage levels and current levels less than 100 ma. Shielding is required.

c. Analog outputs (normally 4-20 mA). Same as b.

d. Contact inputs - use twisted pairs and run in separate conduit.

e. Contact outputs - same as d.

f. Pulse inputs - same as d.

3. Signal and Shield Grounding

a. All shields must be grounded at one point only as close as possible to the signal source.

b. Thermocouples may be grounded or ungrounded.

c. Analog signals, if grounded, should be grounded as near the signal source as possible.

d. Resistance bulbs should not be grounded.

4. Signal and Wiring Separation

a. Analog signals shall be run in a separate conduit from contact or pulse signals.

b. A minimum separation of 12 inches between analog signal leads and a-c power leads should be maintained. For a-c power leads carrying 100 amps or greater, a 24 inch separation should be maintained. Parallel runs should be limited to less than 500 feet. Perpendicular runs may be as close as 6 inches.

E. Submersible pump Power Cable

1. Power cables for submersible pumps shall be of the extra hard usage type suitable for submerged duty and able to withstand common corrosive agents found in water and wastewater. They shall be provided with high grade non-magnetic stainless steel relief cable grips installed at the pump end and high grade non-magnetic stainless steel support cable grips anchored to the wet well structure where they enter the wet well. The strain relief and support cable grips shall be as manufactured by Kellems, Slater/Flexcor, or equal. Non-metallic corrosion resistant grips may be used in lieu of stainless steel if available for the cable size.

F. Ethernet Cables

1. Ethernet cables shall be **shielded** Category 6 rated.

2. Ethernet cables inside VFD cabinets shall be Category 6 rated and shielded.

3. For connections to plant SCADA systems and equipment in supervisory control centers and operator workstations, motor controls centers, switchboards and control panels, etc., provide 4-pair **shielded** twisted pair cabling meeting EIA/TIA Cat 6. Provide with BLUE jacket.
4. Industrial Ethernet cable shall be 24AWG, shielded with polyolefin insulation, aluminum foil polyester shield and PVC outer jacket rated for WET location.

G. Fiber Optic Cable Systems

1. Fiber optic communications cable shall be 36 strand.

2. Fiber optic CCTV cable shall be 36 strand.

2. Provide riser rated, loose tube, gel-free, TrayOptic as manufactured by Belden. The cable shall be UL listed OFNR for use in building riser shafts and floor-to-floor runs. Cable shall be suitable for indoor and outdoor applications including installation in underground ducts and direct burial.
3. Individual fibers shall be ISO 9314 (FDDI) specifications for local area network applications at 100Mbps with 62.5um diameter glass core, a 125um diameter glass cladding and a 245um diameter UV cured acrylate primary buffer. The fibers shall be Gigabit Ethernet grade.
4. For connection to network, provide end connectors from cable manufacturer. The connector ferrule shall be ceramic or glass-in-ceramic, metallic or equivalent. Provide heat shrink tubing section where cable is broken out to protect jacketing. Provide and terminate all fibers of all cables. Coordinate connector types with network equipment provided.

H. Devicenet cable

1. 4 conductor shielded cable with PVC jacket. Conductors shall be tinned copper, 600volt class 1 as manufactured by Belden or equal. Conductor sizes shall be as determined by the contractor for the final devicenet system layout using thick, middle and thin gauge conductors.

3.02 FIELD QUALITY CONTROL

A. Testing

1. All testing shall be performed in accordance with the requirements of the General Conditions and Division 1. The following tests are required:

    a. Witness Shop Tests

        1) Not required.

    b. Shop Test

        1) Cable and wiring shall be tested in accordance with the applicable ICEA Standards. Wire and cable shall be physically and electrically tested in accordance with the manufacturer's standards.

    c. Field Tests

        1) Field testing shall be done in accordance with the requirements specified in the General Conditions, Division 1, and NETA acceptance testing specifications.

        2) After installation, all wires and cables shall be tested for continuity. Testing for continuity shall be "test light" or "buzzer" style.

        3) After installation, all wires and cables shall be tested for insulation levels. Insulation resistance between conductors of the same circuit and between conductor and ground shall be tested. Testing for insulation levels shall be as follows:

            - For 600V power and control cable, apply 1,000 VDC from a Megohmeter for one (1) minute for <u>all</u> 600V wires and cables installed in lighting, control, power, indication, alarm and motor feeder circuits. Resistance shall be no less than 100 Megohms.

            - 600V instrumentation signal cable shall be tested from conductor to conductor, conductor to shield, and conductor to ground using a Simpson No. 260 volt-ohmmeter, or approved equal. The resistance value shall be 200 Megohms or greater.

2. Low voltage wires and cables shall be tested before being connected to motors, devices or terminal blocks.

3. Voltage tests shall be made successively between each conductor of a circuit and all other conductors of the circuit grounded.

4. If tests reveal defects or deficiencies, the Contractor shall make the necessary repairs or shall replace the cable as directed by the Engineer, without additional cost to the Owner.

5. All tests shall be made by and at the expense of the Contractor who shall supply all testing equipment. Test reports shall be submitted to the Engineer.

END OF SECTION

SECTION 16130 - RACEWAYS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. This section of the Technical Specifications includes all raceways for accommodation of electrical conductors, communications conductors, sleeves for underground electrical installations, conduit stubs for future installations, fittings therefore and accessories.

B. All raceways shall be marked with the manufacturer's name or trademark as well as type of raceway and size. This marking shall appear at least once every 10 feet and shall be of sufficient durability to withstand the environment involved. All raceways shall be furnished and installed as outlined under Part 3 of this Specification.

C. All raceways and fittings shall be painted to match existing or surrounding surfaces except in mechanical spaces.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Tubular Raceways

1. Steel, Galvanized, Rigid, Heavy-Wall, Threaded – "Wheatland Tube Co.," "Triangle," "Allied Tube & Conduit Corp.," or equal.

2. Plastic (PVC); Type A (Thin Wall); Type 40 (or Schedule 40); Type 80 (or Schedule 80) (Heavy -Wall) – "Carlon," "Cantex," or equal.

3. Flexible Metal Conduit – "AFC," "Southwire," or equal.

4. Liquidtight Flexible Metal Conduit – "Carol Cable Co., Inc.," "Superflex," "OZ Gedney," or equal.

5. Liquid-Tight Flexible Non-Metallic Conduit - Type "LNM-P" as manufactured by Electri-Flex, Type "Ultralite" as manufactured by Southwire, Type "CNP" as manufactured by Anaconda, or equal.

6. Aluminum Conduit - "Wheatland Tube Co.", "Allied Tube & Conduit Corp.", or equal.

7. PVC Coated Metallic Conduit (PCMC) - "Plasti-Bond Red" as manufactured by Robroy Industries, "OCAL-Blue" as manufactured by Ocal, Inc., Perma-Cote Supreme by Perma-Cote Industries, or equal.

B. Raceway Fittings

1. Conduit fittings – "Crouse-Hinds," "Appleton," "OZ Gedney," or equal.

2. Non-metallic conduit fittings –"Carlon," "Cantex," or equal.

3. Flexible conduit fittings – "Raco," "T & B," "OZ Gedney," or equal.

4. PVC Coated Metallic Conduit fittings - "Plasti-Bond Red" as manufactured by Robroy Industries, "OCAL-Blue" as manufactured by Ocal, Inc., Perma-Cote Supreme by Perma-Cote Industries, or equal.

2.02 MATERIALS

A. Rigid Steel Conduit

1. Rigid steel conduit and fittings shall be of mild steel piping, galvanized inside and out, and shall conform to UL standards. The conduit and fittings hall be listed and labeled by UL as well. The galvanized coating of zinc shall be of uniform thickness applied by the hot-dipped process, and shall be applied also to the threads. It shall be further dipped in a chromic acid bath so as to chemically form a corrosion resistant protective coating of zinc chromate which has a characteristic yellow-green color. Each piece of conduit shall be straight, free from blisters and other defects, cut square, and taper reamed. It shall be delivered with plastic protectors on the threads.

B. Polyvinylchloride (PVC) Conduit

1. PVC conduit and fittings shall be Schedule 40, 80 heavy wall, or thinwall, as indicated in these Specifications manufactured to conform to UL standards. It shall be listed and labeled by UL. It shall have at least the same temperature rating as the conductor insulation. Expansion joints shall be used as recommended by the manufacturer in published literature. PVC systems shall be 90 degrees Celsius minimum UL rated, have a tensile strength of 7,000 psi @ 73.4 degrees Fahrenheit, flexural strength of 11,000 psi and compressive strength of 8,000 psi.

C. Flexible Conduit

1. Flexible metallic conduit shall be constructed from flexibly or spirally wound aluminum. Connections shall be by means of galvanized malleable iron squeeze type fittings, or tomic twist-in type in sizes not exceeding 3/4 inch. Liquidtight conduit shall be light gray in color and have sealtight fittings, type UA.

2. In hazardous locations where flexible connections are required, flexible couplings UL listed for the application shall be used. The couplings shall consist of stainless steel tubing and outer braid, with insulating liner. Female end fittings shall also be stainless steel, with removable steel close nipples. Couplings shall be O-Z/Gedney, or equal.

D. Liquid-Tight Flexible Metal Conduit

1. Liquid-tight flexible conduit (LFMC) shall be aluminum, single strip, with a copper strip interwoven and suitable as a grounding means. LFMC shall be UL listed. LFMC shall have an extruded moisture and oil-proof PVC jacket.

2. PVC coated or stainless steel watertight connectors shall be used with liquid-tight flexible metal conduit on both ends.

E. Liquid-Tight Flexible Non-Metallic Conduit

1. Liquid-tight flexible non-metallic conduit (LFNC) shall be constructed of PVC. LFNC shall be UL listed. LFNC shall have an extruded moisture and oil-proof PVC jacket.

2. Watertight connectors shall be used with liquid-tight flexible non-metallic conduit on both ends. LFNC shall be used to connect all vibrating equipment installed in sodium hypochlorite storage and transfer areas as specified herein, and other applications as directed by the Engineer or as indicated on the drawings.

F. Aluminum Conduit

1. Aluminum conduit shall be extruded from alloy 6063 and shall be the rigid type, non-toxic, corrosion resistant, and non-staining. It shall be manufactured per UL standards as well as listed/labeled by same.

2. Fittings, boxes, and accessories used in conjunction with aluminum conduit shall be die cast, copper free type. They shall be resistant to both chemical and galvanic corrosion. All covers shall have neoprene gaskets.

3. All aluminum conduit used for this project shall be UL listed for the purpose.

G. PVC Coated Metallic Conduit

1. PVC coated rigid aluminum conduit (PCMC) shall be rigid aluminum conduit covered with a bonded 40 mil (minimum) thickness PVC jacket and coated inside with urethane. The conduit shall comply with NEMA RN-1.

H. Conduit Fittings

1. Rigid Steel Conduit Fittings

a. Standard threaded couplings, locknuts, bushings, and elbows made only of steel or malleable iron are acceptable. Integral retractable type IMC couplings are acceptable also.

b. Locknuts: Bonding type with sharp edges for digging into the metal wall of an enclosure.

c. Bushings: Metallic insulating type, consisting of an insulating insert molded or locked into the metallic body of the fitting. Bushings made entirely of metal or nonmetallic material are not permitted.

d. Erickson (union-type) and set screw type couplings: Approved for use in concrete are permitted or use to complete a conduit run where conduit is installed in concrete. Use set screws of case hardened steel with hex head and cup point to firmly seat in conduit wall for positive ground. Tightening of set screws with pliers is prohibited.

e. Sealing fittings: Threaded cast iron type. Use continuous drain type sealing fittings to prevent passage of water vapor. In concealed work, installed fittings in flush steel boxes with blank coverplates having the same finishes as that of other electrical plates in the room.

f. Fittings for PVC coated rigid conduit shall be manufactured by the maker of the conduit.

2. Rigid Aluminum Conduit Fittings

a. Standard threaded couplings, locknuts, bushings, and elbows: Malleable iron, steel or aluminum alloy materials. Zinc or cadmium plate iron or steel fittings. Aluminum fittings containing more than 0.4 percent copper are prohibited.

b. Locknuts and bushings: As specified for rigid steel and IMC conduit.

c. Set screw fittings: Not permitted for use with aluminum conduit.

3. Expansion and Deflection Couplings

a. Accommodate 1.9 cm (0.75 inch) deflection, expansion, or contraction in any direction, and allow 30 degree angular deflections.

b. Include internal flexible metal braid sized to guarantee conduit ground continuity and fault currents in accordance with UL, and the NEC code tables for ground conductors.

c. Watertight, seismically qualified, corrosion-resistant, threaded for and compatible with rigid or intermediate metal conduit.

d. Jacket: Flexible, corrosion-resistant, watertight, moisture and heat resistant molded rubber material and stainless steel jacket clamps.

PART 3 - EXECUTION

3.01 PREPARATION

A. Exterior underground metallic conduits shall be degreased, pretreated, and coated with 2 coats of Carboline 888 epoxy, or equal. Other finishes may be acceptable upon the Engineer's review.

3.02 INSTALLATION

A. Conduit

1. All conduit shall be installed in a first class workmanship manner. It shall be installed in horizontal and vertical runs in such a manner as to ensure against trouble from the collection of trapped condensation and shall be arranged so as to be devoid of traps wherever possible. Special care shall be used in assuring that exposed conduit runs are parallel or perpendicular to walls, structural members, or intersections of vertical planes and ceilings. No open wiring is allowed.

2. Fittings or symmetrical bends shall be required wherever right angle turns are made in exposed work. Bends and offsets shall be avoided wherever possible, but where necessary, they shall be made with an approved conduit bending machine. All conduit joints shall be cut square, reamed smooth and drawn up tight, using couplings intended for the purpose. All threaded ends of conduits shall be coated with an approved conducting compound as manufactured by Thomas & Betts, or equal prior to making up the joint.

3. Conduits shall be securely fastened to all sheet metal outlets, junction and pull boxes with double galvanized locknuts and insulating-grounding bushings as required by the NEC. Conduit crossings in insulating roof fill will require both conduits to be secured to the roof deck, and these crossings can only be made where the insulating fill is a minimum of 3 inches deep. Runs of exposed conduit shall be supported in accordance with the NEC using cast aluminum one hole pipe straps with spacers to provide an air space behind the conduit. Stainless steel minerallaac, one piece conduit clamps shall be acceptable where located such that building occupants are not in danger of inadvertent contact, since this type fitting has several sharp edges. In general terms, they may be considered in areas such as on or above ceilings, or high on walls. All conduit in walls and slabs shall be securely braced, capped (wooden plugs are prohibited), and fastened to the forms to prevent dislodgement during vibration and pouring of concrete.

4. During construction, all conduit work shall be protected to prevent lodgement of dirt, plaster or trash in conduits, fittings or boxes. Conduits which have been plugged shall be entirely freed of accumulations or be replaced. All conduits in floors or below grade shall

be swabbed free of debris and moisture before wires are pulled. Crushed or deformed conduit shall not be permitted.

5. Where GRS conduit penetrates a floor slab the conduit shall be painted with 2 coats of Koppers Bitumastic 300-M or equal to a point 6 inches above the penetration.

6. The final section of conduit connecting each motor or piece of utilization equipment subject to vibration shall be of the flexible type. Type “UA” shall be used in all process areas and in outdoor or wet locations. Flexible conduit to space heaters shall be long enough to allow swivel action.

7. All underground conduits entering a building shall be sealed against water/condensate entering around the conductors. All conduits entering or leaving the main electric room, pipe gallery, wet well, grit room and lower bar screen area shall be sealed against water/condensate and air transfer. Sealant shall be non-hardening dielectric putty.

8. In certain situations, conduit expansion joints shall be required to ensure against conduit and/or cable damage due to settling or thermal expansion and contraction. These expansion joints shall be required where required by the manufacturer or the Contract Drawings and shall be installed per manufacturer’s instructions.

9. Aluminum conduits shall not be in contact with concrete surfaces. Where aluminum conduits are routed along concrete surfaces, they shall be installed with one hole cast straps with clamp-backs to space the conduit ¼” away from concrete surface. Where aluminum conduit passes through concrete, CMU or brick walls, the penetration shall be made such that the aluminum conduit does not come in contact with concrete, CMU, brick or mortar. All penetrations shall meet or exceed the UL design standards. Aluminum conduit shall transition to PVC coated steel conduit where entering a concrete encasement, floor or ductbank.

10. Unless specifically identified on the Drawings as "Direct Buried," all conduits in the earth, including conduits below slabs-on-grade, shall be concrete encased. Joints in conduit shall be staggered so as not to occur side by side. Rigid non-metallic (PVC) conduit shall be connected to PVC coated rigid steel conduit at the point where it leaves the ground, with the transition to metal conduit occurring inside the concrete encasement. PVC coated rigid steel conduit may transition to non-coated conduit after exiting the encasement. The transition coupling between PVC coated conduit and non-coated conduit shall be PVC coated.

11. It is the general intent that boxes for light fixtures, switches, receptacles, etc. in or on the building be flush mounted with concealed conduit to the device, except in areas designated to have all conduit installed exposed.

12. All metal raceway systems shall be grounding conductive, solidly bonded throughout and grounded in accordance with NEC requirements and/or as noted on the Contract Drawings. In addition, all raceway systems shall be provided with separate grounding conductors.

13. **Minimum conduit size shall be 3/4 inch.** The following table shows the minimum burial depth required for all exterior conduit or cable:

Schedule 80 PVC, Concrete Encased	18"
Schedule 80 PVC, Concrete Encased (for medium voltage service entrance)	42"

14. Wire pulling shall be facilitated by the use of a UL approved pulling compound in pulls over 30 feet in length or where there are 2 or more 90 degree bends. Only

polypropylene, nylon, or manila pulling ropes will be permitted. **Standard industry recognized wire pulling equipment shall be used.**

15. All conduits entering and leaving instrument enclosures shall be sealed around the wires with silicone caulk.

16. All conduits for emergency lighting systems shall be separate from other building power conduits.

17. Areas of use for each type of conduit:

Location	Schedule 40 PVC	Schedule 80 PVC	Aluminum	PCMC
Electrical Room – Exposed			X	X
Electrical Room – Concealed in Wall		X	X	X
Garage – Exposed			X	X
Garage – Concealed in Wall		X	X	X
Screenings Room – Exposed Only			X	X
Odor Control Room – Exposed			X	X
Odor Control Room – Concealed in Wall		X	X	X
Chemical Storage Areas		X		
Restroom – Concealed Only		X	X	X
Janitor's Closet – Exposed			X	X
Janitor's Closet – Concealed in Wall		X	X	X
Valve Vault – Exposed Only			X	X
Attic Space			X	X
Exterior Exposed				X
Exterior Underground, Underslab, or In Slab		X	PVC Coated	
Exterior Underground Service Entrance (Primary and Sec.)		X	PVC Coated	

18. All conduit shall have an insulated ground wire pulled to all equipment and receptacles.

19. All raceway runs are shown diagrammatically to outline the general routing of the raceway. The installation shall be made to avoid interference with pipes, ducts, structural members or other equipment. Should structural or other interference prevent the installation of the raceways, or setting of boxes, cabinets, or the electrical equipment, as indicated in the Drawings, deviations must be approved by the Owner, and after approval, shall be made without additional charges and shown on the Record Drawings.

20. Assure conduit installation does not encroach into the ceiling height head room, walkways, or doorways.

21. No conduit shall be run exposed across roofs without first obtaining permission from the Engineer.

22. Conduit may be run inside concrete slabs as long as the slab is at least 6-inches thick and conduit will have at least 1 2-inches of cover on both sides.

23. Runs of flexible conduit above accessible ceilings shall be limited to 10 ft. Runs of exposed flexible conduit shall be limited to 5 ft. All runs of flexible conduit shall be supported in accordance with NEC requirements.

24. All PVC coated conduit shall be installed in accordance with manufacturer's instructions. The Contractor shall use tools that are specifically suited for coated conduit systems. The use of pipe wrenches and other such tools on PVC coated RGS conduit is prohibited. The Engineer and Owner reserve the right to reject any installation of coated conduit that does not meet the requirements of the Section or the manufacturer's instructions. The Engineer and Owner also reserve the right to reject any installation that exhibits damage due to the improper use of tools. All rejected installations shall be replaced by the Contractor at no additional cost to the Owner. The use of PVC coated conduit repair compounds to repair damages or improper installation is prohibited.

25. All Contractor personnel that install PVC coated RGS conduit shall be trained by the PVC coated RGS conduit manufacturer. Training shall include proper conduit system assembly techniques, use of tools appropriate for coated conduit systems, and field bending/cutting/threading of coated conduit. The Contractor shall furnish evidence of such training as specified herein. Training shall have been completed within the past 24 months prior to the Notice to Proceed on this Contract for all coated conduit installation personnel. Contractor personnel not trained within this timeframe shall not be allowed to install coated conduit, or shall be trained/re-trained as required prior to commencement of conduit installation.

26. Sealing fittings shall be installed where conduits pass from non-hazardous locations to hazardous locations and as required by Chapter 5 of the NEC. See section 16050 for hazardous area classifications.

27. All raceways for instrumentation and fiber optic communication systems shall use Mogul style pulling elbows above grade and log sweep factory 90's below grade

28. No more than three (3) 90 degree bends (maximum 270 degrees total) will be allowed in any one conduit run. Where more bends are necessary, a condulet or pull box shall be installed.

29. Weatherproof, aluminum, insulated throat "Meyers" hubs shall be used on all conduit entries to boxes and devices without integral hubs in process areas to maintain NEMA 4X integrity. The Contractor shall furnish and install Meyers" hubs on all conduit entries into non-cast enclosures such as metallic or non-metallic control panels, control equipment enclosures, wireways, pull boxes, junction boxes, control stations, and similar type equipment when this type of equipment is located in process areas requiring NEMA 4X integrity. This requirement for "Meyers" hubs does not apply to any areas of the plant facilities where NEMA 4X integrity is not required.

END OF SECTION

SECTION 16131 - BOXES

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Outlet and junction boxes shall be furnished and installed where indicated on the Contract Drawings, and\or as required by the work in accordance with the NEC.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Boxes – "Wiegmann," "Appleton," "Raco," "Crouse-Hinds," "Hoffman," "Robroy Industries," "Spring City," "Carlon," or equal.

2.02 GENERAL

A. All junction and/or pull boxes for dry (non-corrosive) areas shall be of code gauge sheet metal construction, of the inside dimensions as required by code, with covers.

B. Outlet boxes for wet or damp locations shall be cast metal, rust and corrosion resistant (NEMA 4X), with at least 5-1/2 full threads for each (bossed) conduit opening, and shall be suitable for flush or surface mounting as required with drilled external, cast mounting extensions (bossed to provide at least 1/8" between back of box and mounting surface for drainage). Box covers shall be hinged or cap screw retained as required, of the same material as the box and provided with stainless steel (rustproof) hardware.

C. Junction and/or pull boxes for out-of-doors use or indoor process areas, not mounted in concrete may be sheet metal (NEMA 4X), waterproof, rustproof, rain and sleetproof, with hinged covers and latches and provided means of locking by means of keyed locks, tamper-resistant screws or padlocking as required and with clamping cap-screws top and bottom door edges to provide firm contact with gasketing. All gaskets shall be molded (unbroken) neoprene or butyl rubber.

D. NEMA 4X junction and/or pull boxes may be stainless steel, if called for on the Contract Drawings; or non-metallic or cast aluminum.

E. Underground junction or pull boxes shall be constructed of reinforced concrete cast-in-place or pre-fabricated as detailed on the Contract Drawings.

F. Junction boxes for use in wet-wells and other hazardous areas shall be watertight, rustproof and corrosion resistant, and explosion proof with threaded conduit openings (5-1/2 full threads - minimum) and provided with rustproof hardware.

G. Explosionproof sealing fittings shall be furnished and installed in accordance with NEC requirements. Fittings shall be aluminum and shall be split (EYSR) construction type.

H. Junction and/or pull boxes for chemical storage and transfer areas shall be Schedule 80 PVC where Schedule 80 PVC conduit is specified in 16130.

PART 3 - EXECUTION

3.01 INSTALLATION, APPLICATION, AND ERECTION

A. General

1. Outlets shall be installed in the locations shown on the Contract Drawings. The Contractor shall study the general building plans in relation to the space surrounding each outlet, in order that his work may fit the other work required by these Specifications. When necessary, the Contractor shall relocate outlets so that when fixtures or other fittings are installed, they will be symmetrically located according to room layout and will not interfere with other work or equipment.

2. All supports for outlet boxes shall be furnished and installed by the electrical trades.

B. Concealed Work

1. All outlet boxes shall be standard galvanized steel type at least 2 inches deep, single or gang type of size to accommodate devices shown. Exceptions shall be noted on the Contract Drawings.

2. Standard deep type outlet boxes (concrete rings with appropriate covers) shall be used in floor slab construction so concealed conduits entering sides of boxes can clear reinforcing rods.

3. Outlet boxes for concealed telephone and signaling systems shall be the 4-inch square type, unless otherwise noted or required by the telephone company.

4. Boxes for use in masonry construction shall be 2-1/2 inches deep for 4-inch block and 3-1/2 inches deep for 6- and 8-inch block. Through wall boxes are prohibited for outlets opposite each other.

C. Exposed Work

1. Outlet or junction boxes for use with exposed aluminum conduit shall be copper free, cast aluminum type.

2. Outlet or junction boxes for use with exposed PVC conduit shall be PVC.

D. Pull Boxes

1. Pull boxes for exterior underground work are shown on the Contract Drawings and are the minimum number required. Others may be added at the Contractor's option, but no extra pay shall be allowed. Interior pull boxes are not shown but shall be used as needed. Pull box types are as follows:

   Exterior - Per detail on the Contract Drawings.

   Interior - Interior pull boxes in dry areas shall be of code gauge steel of not less than the minimum required by the NEC and shall be provided with hinged covers. In wet areas or pipe galleries, they shall be rated watertight, of stainless steel, cast aluminum, PVC, fiberglass, or equal. Hardware shall be stainless steel.

E. Openings in Electrical Boxes

1. All openings in electrical equipment, enclosures, cabinets, outlet and junction boxes shall be by means of welded bosses, standard knockouts, or shall be sawed, drilled, or

punched with tools specially made for the purpose. The use of a cutting torch is prohibited. Unused openings shall be plugged per the NEC.

END OF SECTION

SECTION 16140 - WIRING DEVICES

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Wiring devices shall be installed where indicated on the Contract Drawings.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Hubbell,” “Eagle,” “General Electric,” “Wiremold,” “P&S,” “Leviton,” “Daniel Woodhead,” or equal.

2.02 EQUIPMENT

A. Receptacles

1. Twin-convenience - outlet (interior) – “Hubbell” cat. no. 5362, or equal.

2. Twin-convenience - outlet (exterior) – “Hubbell” cat. no. 5362 with Taymac Corporation or Intermatic, Inc. safety outlet enclosure.

3. Special purpose outlet - Per equipment requirements.

4. Ground fault interrupting receptacles shall be required where shown on the Contract Drawings, and shall be indicated by the abbreviation “GFI” beside the circuit symbol on the Contract Drawings. They shall be rated 20 amps (125 volts) and shall be of the duplex, feed through type, capable of protecting all downstream receptacles on the same circuit. They shall be UL listed and interrupt the current between 4-6 milliamps of ground fault leakage. Appropriate plates shall be furnished and installed. The 20 ampere rating shall apply not only to device internals but to the faceplate as well.

B. Plates and Covers

1. Furnish and install plates of the appropriate type and size for all wiring and control devices, signal and telephone outlets.

2. All plates on flush and surface mounted boxes shall be of 302 stainless steel (nonmagnetic) with rounded or beveled edges, except where weatherproof covers are shown. All device plate screws shall be nylon or stainless steel with countersunk heads. Plates shall be installed vertically and with an alignment tolerance of 1/16 inch. Device plates shall be of the one-piece type, of suitable shape for the devices to be covered. Plates shall have a smooth finish with no crevices to collect dirt. Oversize plates are not acceptable.

3. Covers for boxes serving equipment where flexible conduit is to be tapped into cover plates shall be sheet metal drilled for conduit. Gaskets shall be required as well as all special adapters for mounting.

C. Wall Switches (Tumbler Type)

1. Single pole (interior) – “Hubbell” cat. no. 1221, or equal.

2. Single pole (exterior) – “Hubbell” cat. no. 1222, or equal, and Hubbell 1795 or equal plate.

3. 3-way switches (interior) – “Hubbell” cat. no. 1223, or equal.

4. 4-way switches (interior) – “Hubbell” cat. no. 1224, or equal.

5. Outside receptacles shall be labeled for the purpose.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Wall Switches

1. Wall switches shall be mounted at a height as indicated in Section 16050, unless otherwise noted on the Contract Drawings.

B. Receptacles

1. Outlets shall be located as shown on the Contract Drawings. Where located in special interior finishes, they shall be properly centered. Boxes shall be of the type noted and accepted for the specific installation.

2. Furnish and install receptacle circuits where called for on the Contract Drawings and/or by these Specifications. Circuits shall be installed in conduit from panel to receptacle, with flush mounted boxes except as noted on the Contract Drawings.

3. Receptacles and lighting circuits shall not be combined on the same overcurrent device. For runs over 75 feet or for 30 amp receptacles, minimum wire size shall be AWG No. 10.

4. Receptacles for specific devices (i.e., air conditioner), shall be rated at the correct voltage and amperage for that unit.

5. The minimum free length of conductor at each box for the connection of a fixture, switch or receptacle shall be 8 inches. All connections shall be made mechanically and electrically secure.

6. Receptacles shall be duplex type, rated at 20 amps, 125 volts, brown colored, unless otherwise noted. Mounting height shall be as specified for low outlets in Section 16050. All receptacles shall be of the grounding type.

7. Receptacles over workbenches or countertops or at medium or high mountings shall be mounted so that the grounding slot is below the neutral and hot. All other receptacles shall be mounted with the grounding slot above the neutral and hot.

8. Exterior weatherproof receptacles, shall be weatherproof while in use. This requirement shall apply on all outdoor units and on others as indicated on the Drawings. To meet this requirement, appropriate safety outlet covers as manufactured by Taymac Corporation, Intermatic Guardian Series, or equal shall be utilized in these areas.

END OF SECTION

SECTION 16150 - WIRE CONNECTIONS AND CONNECTING DEVICES

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Wire connection and connecting devices shall be as herein specified.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Connectors, Lugs, etc. – “T & B”, “Anderson”, “Burndy”, or equal.

B. Termination and splice connectors – “3M Scotchlok”, “Anderson”, “T & B”, “Burndy”, or equal.

2.02 MATERIALS

A. Wire Splicing and Terminations (600 Volts and Below)

1. Electrical Terminal and Splice Connectors (#22 - #4 AWG)

a. Terminals and splice connectors from #22 - #4 AWG shall be compression types with barrels to provide maximum conductor contact and tensile strength. Performance, construction, and materials shall be in conformance with UL standards for wire connectors and rated for 600 volts and 105 degrees Celsius.

b. Connectors shall be manufactured from high conductivity copper and entirely tin plated. Terminal barrels shall be serrated on the inside surface and have a chamfered conductor entry. Terminals shall have funnel entry construction to prevent strand fold-back. All barrels shall be brazed seam or seamless construction.

c. Spade type terminals shall be sized for the appropriate stud and shall be locking type that snap firmly onto studs with a close fit for maximum retention. Spade type terminals shall be insulated with an insulation suitable for maintaining a high dielectric strength when crimped and be made form nylon, PVC, or equal.

2. Electrical Lugs and Connectors (#6 AWG - 1000 Kcmil)

a. Lugs and splice connectors from #6 AWG - 1000 Kcmil shall be compression types with barrels to provide maximum conductor contact and tensile strength. They shall be manufactured from high conductivity copper and entirely tin plated. They shall be crimped with standard industry tooling. The lugs and connectors must have a current carrying capacity equal to the conductors for which they are rated and must also meet all UL requirements. All lugs above 4/0 AWG shall be 2 hole lugs with NEMA spacing. The lugs shall be rated for operation through 35 KV. The lugs shall be of closed end construction to exclude moisture migration into the cable conductor.

3. Twist-on Wire Connectors (#22 AWG - #10 AWG)

a. All twist-on wire connectors must have a corrosion resistant spring that is free to expand within a steel jacket. The steel jacket must be insulated with a flexible vinyl jacket capable of withstanding 105 degrees Celsius ambient temperatures and of sufficient length to cover wires that are inadvertently overstripped.

b. Each connector size must be listed by UL for the intended purpose and color coded to assure that the proper size is used on the wire combinations to be spliced. The

connectors must be compatible with all common rubber and thermoplastic wire insulations.

4. Solderless/re-usable lugs shall be used only when furnished with equipment such as control panels, furnished by others, where specification of compression type lugs is beyond the Contractor's control. In the event their use is necessary, the Contractor shall be responsible for assuring that they are manufactured to NEMA standards, with proper number and spacing of holes and set screws.

PART 3 - EXECUTION

3.01 INSTALLATION, APPLICATION, & ERECTION

A. Insulation of Splices and Connections

1. Connections/splices with a smooth even contour shall be insulated with a conformable 7 mil thick vinyl plastic insulating tape which can be applied under all weather conditions and is designed to perform in a continuous temperature environment up to 105 degrees Celsius. The tape shall have excellent resistance to abrasion, moisture, alkalies, acids, corrosion, and varying weather conditions (including sunlight). The tape shall be equal to Scotch 33+ and shall be applied in conformance with manufacturer's recommendations. In addition, it shall be applied in successive half-lapped layers with sufficient tension to reduce its width to 5/8 of its original width. The last inch of the wrap shall not be stretched.

2. Connections/splices with irregular shapes or sharp edges protruding shall be first wrapped with 30 mil rubber tape to smooth the contour of the joint before being insulated with 33+ insulating tape specified in the previous paragraph. The rubber tape shall be high voltage (69 KV) corona-resistant based on self-fusing ethylene propylene rubber and be capable of operation at 130 degrees Celsius under emergency conditions. The tape must be capable of being applied in either the stretched or unstretched condition without any loss in either physical or electrical properties. The tape must not split, crack, slip, or flag when exposed to various environments. The tape must be compatible with all synthetic cable insulations. The tape must have a dissipation factor of less than 5 percent at 130 degrees Celsius, be non-vulcanizing, and have a shelf life of a least 5 years. The rubber tape shall be applied in successive, half-lapped wound layers and shall be highly elongated to eliminate voids. Other manufacturer's recommendations on installation shall be adhered to. The rubber tape shall be equal to Scotch 23 or 130C electrical splicing tape.

3. Splices made in wet or damp locations shall be made submersible and watertight with special kits made for the application and compatible with type of cables employed.

B. Connection Make-up

1. Connections of lugs to bus bars, etc., shall be made up with corrosion resistant steel bolts having non-magnetic properties with matching nuts, and shall utilize a Belleville spring washer (stainless steel) to maintain connection integrity. Connections shall be torqued to the proper limits. Prior to bolting up the connection, electrical joint compound shall be brushed on the contact faces of the electrical joint.

2. All motor lead connections shall be made up to match the type of lead furnished on the motor. If the lead is not lugged, then twist-on wire connectors may be used. To prevent possible vibration problems, twist-on connectors shall be taped after installation.

3. All lugged motor lead connections (excluding motors over 200 horse-power) shall be made up using ring tongue compression lugs with proper size stainless steel nuts and bolts. Belleville type spring shall be used to maintain tension on the connections. The

connections shall then be insulated using the procedure described for irregular shapes, utilizing rubber tape in conjunction with vinyl electrical tape.

4. At the time of final inspection, the Engineer may request the Contractor to disassemble 3 randomly selected motor lead connections in the Engineer's presence, to assure conformance with these Specifications.

5. The Contractor shall include all necessary tools, materials, and labor in his bid for disassembly of the connections and for remaking them with new insulating materials after inspection.

END OF SECTION

SECTION 16170 – SAFETY SWITCHES

PART 1 – GENERAL

1.01 SCOPE OF WORK

A. Provide horsepower-rated, quick-make, quick-break, safety switches provided with the number of poles and fuses as required. When used with variable speed drives, provide auxiliary contacts to open before switch opens and e-stop with red mushroom head on cover. Wire e-stop and auxiliary contact in series.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS/EQUIPMENT

A. Safety switches shall be as manufactured by Square D Company.

B. Switches shall be NEMA Type HD, single-throw, externally operated, non-fused or fused with Class R fuse clips.

C. Switches shall have arc shields, shall be of enclosed construction and fusible or non-fusible as indicated. Switches shall be rated for either 250-volt AC or 600-volt AC service as required.

D. All switches shall be capable of interrupting locked rotor current of motor which it serves.

E. Enclosures shall be NEMA-1 for interior non-process area use and NEMA-4X for exterior and process area use unless noted otherwise.

F. Provide dual-element Bussman type FRN (250 volt) or type FRS (600 volt) fuses for any fusible safety switch serving a motor circuit.

G. For non-motor loads, provide dual element Bussman type LPN (250 volt) or type LPS (600 volt).

H. All switches shall be capable of being padlocked in either the “On” or “Off” position.

I. Safety switches shall be provided with auxiliary contacts where indicated on Contract Drawings.

J. Safety switches shall be UL listed and shall conform to NEMA Standards. NEMA 4X enclosed safety switches where called for shall be 316 stainless steel. Enclosures for switches located in sodium hypochlorite storage or transfer areas shall be NEMA 4X non-metallic.

K. NEMA 1 enclosed switches shall be phosphate coated as equivalent, code gauge steel with baked enamel finish.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Provide non-fusible switches at remote motor locations as indicated on drawings.

B. Provide fusible disconnects at package A/C units, fused as specified on unit nameplate.

C. Mount switches to walls or to equipment enclosures with a minimum of 4 bolts using toggle anchors for masonry construction, Phillips “Red Head” anchors for poured concrete construction and bolts, jumbo washers, lock washers and nuts for equipment enclosure mounting.

D. All safety switches to be identified with nameplates per Section 16075.

END OF SECTION

SECTION 16220 - MOTORS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Motors are to be furnished with driven equipment except where otherwise noted on the Contract Drawings or elsewhere in this Division of the Specifications. All motors shall conform to the following Specifications and any special requirements of the driven equipment. Special requirements of the driven equipment shall take precedence over these Specifications should a discrepancy occur. Starting torque and slip ratings shall conform to the requirements of the driven equipment.

B. Polyphase motors shall be of the squirrel cage induction type and single phase of the capacitor start-induction run type except as otherwise noted. Conduit boxes shall be tapped for the size conduit shown on the Contract Drawings.

C. All motors shall be manufactured and installed in accordance with applicable NEMA standards and NEC provisions, latest revisions.

1.02 DELIVERY, STORAGE, & HANDLING

A. All electrical motors shall be protected against the accumulation of moisture, dust and debris and physical damage during the course of installation of the job.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Motors – “General Electric”, “Westinghouse”, “U.S. Motors”, “Gould Century”, “Lincoln”, “Baldor”, “Marathon”, “Reliance”, “Magnatek”, “Siemens”, or equal.

2.02 EQUIPMENT

A. Motors 200 Horsepower and Under for Service Under 600 Volts

1. Ratings and Electrical Characteristics

a. Time: All motors shall be rated for continuous duty.

b. Temperature: Based on NEMA standards for a maximum ambient temperature of 40 degrees Celsius and an altitude of 3,300 feet or less, according to service factor and insulation class employed.

c. Voltage: All single phase motors shall be rated 115/208/230 volts and all polyphase motors 230/460 volts. Submersible polyphase motors to be operated at 460 volts may take exception to the dual voltage requirement. All motors shall be capable of normal operation at balanced voltages in the range of ±10 percent from rated winding voltage.

d. Frequency: All a-c motors shall be rated for 60 Hz. operation. All motors shall be capable of normal operation at frequencies 5 percent above or below the nominal rating of 60 Hz.

e. Horsepower: Horsepower of the motors shall be as given in the Specification Division on the driven equipment or as shown on the Contract Drawings. Submersible motors shall be allowed to be furnished even though the horsepower

rating may not be in accordance with standard NEMA assignments. In many cases, the horsepower specified is a minimum requirement and certain alternate manufacturers may require larger horsepower motors. The larger motor shall be furnished at no extra cost to the Owner.

f. Locked Rotor Current: Locked rotor current shall be in accordance with NEMA standards.

g. Efficiency and Power Factor: Efficiency and power factor shall be given consideration during Shop Drawing review. The ratings at full, 3/4, and 1/2 load shall be compared to similar motors manufactured by acceptable suppliers listed in these Specifications. Excessive variation shall be considered grounds for rejection.

h. Speed: Synchronous speed of motors shall correspond to standard NEMA ratings. Actual speed shall be as given in the Specification Division on the driven equipment. Slip shall not exceed 5 percent at full load.

i. Service Factor: The service factor shall be 1.15 unless requirements of the driven load necessitate a higher service factor. The service factor for inverter duty rated motors shall be 1.0.

j. Insulation Class: Insulation shall be NEMA Class F, except as otherwise noted. Submersible motors shall be Class F, and inverter duty motors to be operated at variable speed shall be Class H. Motors shall operate at a Class B rise at nameplate horsepower loading regardless of Insulation Class.

k. Design Level: Motors shall be NEMA design B, except as otherwise noted.

l. Enclosure: Motors for process equipment 2 HP and smaller shall be totally enclosed. All motors for process equipment larger than 2 HP shall be TEFC (totally enclosed fan cooled), suitable for use indoors or outdoors, except as otherwise noted. Totally enclosed non-ventilated (or air-over) motors may be used for ventilators and other auxiliary equipment that by virtue of the load are provided with more than adequate ventilation. ODP (open dripproof) motors may be used for ventilators where the motor is outside the air stream yet still protected from the weather. Division 15 of the Specifications and the HVAC Contract Drawings will detail the type of enclosure required for ventilators. Submersible motors shall be air or oil filled and of watertight construction. Motors used in classified atmospheres shall be properly rated for that hazard.

m. Frame Size: Frame designations shall be in accordance with NEMA standards.

n. Winding Overtemperature Sensors: All motors 15 horsepower and over shall be provided with motor winding thermostats. The devices shall be hermetically sealed, snap-acting thermal switches, actuated by a thermally responsive bi-metallic disk. A minimum of 1 per phase is required, with switches wired into the control circuit of the starter to provide deenergization should overheating threaten. All submersible motors shall be equipped with motor winding thermostats.

o. All submersible pump/motor assemblies shall be equipped to detect presence of moisture and alarm at the controller.

p. Motors specified for operation with variable frequency drives shall be inverter duty and shall be designed to output 100 percent of nameplate horsepower under continuous duty service without exceeding the temperature rise specified herein when controlled by the actual drives furnished. Inverter duty motors shall be designed to operate down to 10% of full load speed without the need for a line powered cooling fan.

2. Mechanical Characteristics

   a. Integral Horsepower Motor Construction

      1) Motor frames for horizontal motors shall be cast iron, heavy fabricated steel, or cast aluminum (alloy 356 or 360). A steel insert ring shall be set into the aluminum alloy endshield when cast to minimize wear of the bearing support. **Aluminum alloy motors shall not be used in areas where exposed to chlorine gas.**

      2) Motor frames for vertical motors shall be cast iron, heavy fabricated steel, or extruded aluminum (alloy 6063-T4 or 6063-T6). Endshields for vertical motors **must** be cast iron.

      3) If an aluminum frame is used, the endshields and/or all other steel hardware must be plated with zinc or cadmium and coated with grease before assembly to minimize the galvanic action between the steel and aluminum.

      4) Motor frames and endshields shall be of such design and proportions as to hold all motor components rigidly in proper position and provide adequate protection for the type enclosure employed. Lifting lugs of all motors shall conform to NEMA standards.

      5) Windings shall be random or form wound, adequately insulated and securely braced to resist failure due to electrical stresses and vibration. If the windings are aluminum, there shall be a cold welded aluminum-copper transition joint at the termination of the windings to permit the use of standard copper to copper connection techniques by the electrician and to prevent galvanic action between the copper power wires and the aluminum windings.

      6) The motor shaft shall be made of high grade machine steel or steel forging of size and design adequate to withstand the load stresses normally encountered in motors of that particular rating. Bearing journals shall be ground and polished.

      7) Rotors shall be made from high grade steel laminations adequately fastened together and to the shaft. Rotor cage windings may be cast aluminum of bar type construction with brazed end rings.

      8) Integral horsepower motors shall be equipped with cone, roller, or ball bearings made to AFBMA standards, Grade 1 and shall be of ample capacity for the motor ratings. The bearing housing shall be large enough to hold sufficient lubricant to minimize the need for frequent relubrication (ten years normal operation without lubrication), but facilities shall be provided for adding new lubricant and draining out old lubricant without motor disassembly. The bearing housing shall have long, tight running fits or rotating seals to protect against the entrance of foreign matter into the bearings or leakage of lubricant out of the bearing cavity.

      9) See the specification division relating to each piece of motor driven equipment for additional motor requirements to those listed above.

   b. Fractional Horsepower Motor Construction

      1) Motor and shell shall be rigid welded steel designed to maintain accurate alignment of motor components and provide adequate protection. End shields shall be reinforced, lightweight, die cast aluminum. Windings shall be of varnish insulated wire with slot insulation of polyester film and baked on bonding treatment to make the stator winding strongly resistant to heat, aging, moisture, electrical stresses, and other hazards. Motor shafts shall be made from high grade, cold rolled, shaft steel with drive shaft extensions carefully machined to

standard NEMA dimensions for shaft coupled drive connection. Bearings shall be carefully selected precision ball bearings with extra quality, long life grease and large reservoir providing 10 years normal operation without relubrication, AFBMA Grade 1.

c. Submersible Motor Construction

1) See Equipment Specifications.

3. Tests, Nameplates, and Shop Drawings

a. Tests

1) Tests shall be required on integral horsepower motors only. A factory certified test report of "electrically duplicate motors previously tested" shall be supplied on all motors under 200 horsepower. The test shall be certified by the factory and shall contain a statement to the effect that complete tests affirm the guaranteed characteristics published in the manufacturer's catalogs or descriptive literature.

2) Tests will be in accordance with IEEE test procedures.

b. Nameplates

1) Each motor shall have a permanently affixed nameplate of brass, stainless steel, or other metal of durability and corrosion resistance. The data contained on the nameplate shall be in accordance with NEMA standards.

c. Shop Drawings

1) Shop Drawings shall consist of motor dimensions, nameplate data from each motor and tests as outlined above. Also included shall be efficiency and power factor at 100, 75, and 50 percent load. Operation, maintenance, and lubrication information (including bearing catalog numbers) shall be submitted with Shop Drawings for review.

4. Efficiency Requirements

a. The following motor full load efficiency requirements shall be met as a minimum for totally enclosed 3 phase integral horsepower motors, per NEMA test methods:

Horsepower	Nominal 3600 RPM (Minimum %)	Nominal 1800 RPM (Minimum %)	Nominal 1200 RPM (Minimum %)
1	75.5	82.5	80.0
1.5	82.5	84.0	85.5
2	84.0	84.0	86.5
3	85.5	87.5	87.5
5	87.5	87.5	87.5
7.5	88.5	89.5	89.5
10	89.5	89.5	89.5
15	90.2	91.0	90.2
20	90.2	91.0	90.2
25	91.0	92.4	91.7
30	91.0	92.4	91.7
40	91.7	93.0	93.0

Horsepower	Nominal 3600 RPM (Minimum %)	Nominal 1800 RPM (Minimum %)	Nominal 1200 RPM (Minimum %)
50	92.4	93.0	93.0
60	93.0	93.6	93.6
75	93.0	94.1	93.6
100	93.6	94.5	94.1
125	94.5	94.5	94.1
150	94.5	95.0	95.0
200	95.0	95.0	95.0

Open Motors where specified shall also comply with NEMA efficiency minimums.

b. Motors shall be energy efficient type to comply with requirements of the Energy Policy Act of 1992.

B. Motors Over 200 Horsepower for Service Under 600 Volts

1. Motors specified in this section shall comply with the requirements of preceding Section 2.02, Sub-article A unless otherwise noted herein. Motors shall be furnished by the pump supplier to be installed by the Contractor.

2. Motors shall be especially suitable both electrically and mechanically to drive the equipment specified in other divisions. The speed, horsepower, torque, base, bearings, shaft and motor tolerances shall be coordinated closely with the equipment manufacturer's requirements so as to provide a satisfactory, efficient drive without overloading, overheating, or abnormal vibration.

3. Motors shall meet the NEMA temperature rise as defined for Class F insulation. Service factor shall be 1.15 and the motor shall be tested for temperature rise at its service factor load above a 40°C ambient. The service factor for inverter duty rated motors shall be 1.0. All motors shall be dynamically balanced and vibration shall be measured per NEMA methods. Critical speed of the shaft and motor assemble shall be above the operating speed of the motor by at least 10 percent.

4. Motors shall be equipped with nonreverse ratchets to prevent damage to pumps.

5. Bearings shall be selected to have AFBMA rated minimum life of 1 year when operating continuously at rated speed of the motor and at total load consisting of the weight and hydraulic thrust load imposed on the motor by the pump. Angular contact ball thrust bearings, spherical roller thrust bearings, or plate thrust bearings shall be used depending on thrust requirements. Motors shall have oil lubricated thrust and guide bearings, with visual level indicators, accessible drain plugs and accessible filling plugs. Oil lubrication system shall be so designed as to provide the correct quantity of lubricant with minimum foaming or aeration. A nameplate shall be provided on all motors showing bearing numbers and oil type and required viscosity.

6. Motors shall be high thrust capable of carrying 30 percent momentary upthrust.

7. In addition to the test report required in the preceding Sub-article, the manufacturer shall submit data indicating: guaranteed efficiencies and power factor at 100 percent, 75 percent, and 50 percent load; full load current; locked rotor current.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Installation of motors shall comply with motor manufacturer's instructions as well as applicable NEMA recommendations and requirements of the driven equipment OEM (original equipment manufacturer).

B. Motors shall be aligned to acceptable tolerances and shall not vibrate excessively.

C. Motors shall not be energized until they have been accepted by the OEM start up personnel.

END OF SECTION

SECTION 16270 – MEDIUM VOLTAGE TRANSFORMERS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Transformer locations, sizes, connections and voltage/phase shall be as shown on the Contract Drawings, furnished and installed as herein specified.

B. All transformers shall have the KVA rating painted on the exterior in a contrasting color to the enclosure paint color, in a size large enough to be read from a distance (minimum 6" high letters), or from the ground in the case of pole-top units.

C. All transformers shall be non-PCB type.

D. Refer to Section 16437 for neutral ground monitoring, Section 16435 for paralleling to Utility, LF&G KU Interconnect Requirements drawing SPEC-252-C Interconnection Requirements Figure 2 and plan sheet E-4601 for interconnect and PT's on primary for Synchronization relay. Prior to submitting switchgear and MV transformers to engineer or owner, contractor shall submit the transfer scheme and protection to Rodney Brock of LF&G KU for approval and provide written letter of acceptance.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. "Cooper", "Square D", "Eaton", "General Electric", "ABB" or equal.

2.02 FABRICATION

A. Oil Filled Transformer

1. General

a. Oil type transformers shall not make use of oil containing PCB.

2. Pad-mounted, Tamper-proof, Compartmental Type, Mineral Oil Insulated, Self-cooled Transformer

a. The transformer shall be compartmental type, self-cooled, tamper-resistant and weather protected. The transformer shall have a bolted cover with tamper-resistant fastenings. Lifting eyes and jacking pads shall be provided. The tap changing mechanism shall be externally operable and for de-energized operation only. The high and low voltage compartments shall be side by side, separated by a steel barrier with the low voltage on the right. Access to the high voltage compartment cannot be made until the low voltage door has been opened. Doors shall be equipped with lift-off stainless steel hinges and door stops.

b. A removable front sill will allow the transformer to be rolled or skidded. High voltage terminations shall be deadfront-externally clamped one piece integral bushings for loop feed operation. Low voltage bushings shall be molded epoxy with blade type spades. The transformer shall comply with the latest applicable standards of NEMA and ANSI.

c. Additional characteristics and optional features:

Primary Voltage:	12470, Delta
Secondary Voltage	4160/2400, WYE w/low resistance neutral resister and monitoring system, Modbus Ethernet TCP/IP to Control Logix PLC system
Taps:	± 2 - 2 1/2 percent
BIL:	95
Impedance:	4 – 7.5 percent
Temperature Rise:	55°C/65°C above a 30°C ambient
Coolant:	Oil

Fill plug and pressure relief valve
Oil level plug
Lightning arresters, deadfront (elbow type for installation on unused loop feed bushings)
Fusing: ELSP partial range current limiting with expulsion bayonet
No load tap changer - externally operable
Drain valve and sampling device
Gang operated load break switch (under oil)

Paint:	Manufacturer's standard
Windings:	Copper

d. Concrete pad details are shown on the Contract Drawings. Should the transformer offered not fit on the designed pad; cost of modifications and larger pad shall be borne by the Contractor.

e. Provide oil drain and sample port.

f. Provide SEL-2414 transformer monitor or equal to monitor oil temperature, transformer pressure winding temperature (2 RTDs per winding), metering (V.A. kW), transformer thermal monitor per IEEEC57.91-1995. Provide Modbus TCP/IP Ethernet communication.

g. Provide low resistance neutral resistor in NEMA 3R stainless steel enclosure with ground monitoring equipment and MODBUS TCP/IP Ethernet communication.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Transformers shall be furnished and installed in accordance with manufacturer instructions, NEC, and NESC requirements, as well as local utility company requirements.

B. Touch up paint on exterior of enclosure.

C. Anchor to foundation.

D. Provide corrosion inhibitors in oil per manufacturer's recommendations.

E. Provide independent lab testing of oil as follows:

1. At installation prior to applying power, perform oxidation inhibitor content test per ASTM D2668 and dielectric breakdown voltage per D877, ASTM D1816.

2. 30 days after applying voltage, perform tests in (1) above and dissolved gas analysis ASTM D3612, dissolved metals ASTM D7151, water content per IEC814, acidity per

ASTM D974, Interfacial Tension (IFT) per ASTM D971 and Polychlorinated Biphenyl (PCB) per ASTM D4059.

3. 30 days prior to end of warranty period, perform tests in (1) and (2) above.

4. Provide written reports with brief commentary of each test result and the oil's suitability for use.

END OF SECTION

SECTION 16271 - GENERAL LIGHTING AND DISTRIBUTION TRANSFORMERS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Dry-type distribution transformers with primary and secondary voltages of 600V and less and capacity ratings through 2000kVA.

1.2 REFERENCES

A. NFPA 70 - National Electrical Code

B. NEMA ST20

C. Underwriters Laboratory (UL) and Canadian Standard Association

1. UL 1561 – Dry-Type General Purpose and Power Transformers

2. CSA C22.2 No.47-M90 Air-Cooled Transformer (Dry Type)

D. UL 250 Enclosure for Electrical Equipment

E. 2005 Energy Act PUBLIC LAW 109—58—AUG. 8, 2005
Comply with all Rules from Department of Energy

1. 10 CFR 429

2. 10 CFR 431

F. Natural Resources of Canada

1.3 SUBMITTALS

A. Suppliers asking consideration as an approved equal shall submit complete, warranted performance data and physical dimensions for similar transformers. Data shall be submitted for each size specified, and shall be received by the consultant engineer no less than 10 days prior to the bid due date for consideration.

B. Shall Include the following:

1. Copy of ISO 9001:2000 Certification of manufacturing operation.

2. Copy of ISO 14001:2004 Certification of manufacturing operation.

3. Confirmation that transformer(s) are UL 1561 Listed with a K-9 Rating.

4. Construction Details including enclosure dimensions, kVA rating, primary & secondary nominal voltages, voltage taps, unit weight.

a. Wire Access Points – showing Wire Bending Dimensions

b. Location for Ground Lug Provisions – NEC ********

5. Basic Performance characteristics including insulation class, temperature rise, core and coil materials, impedances & audible noise level, unit weight, inrush data RMS.

6. Efficiency Data

7. No load and full load losses will be calculated per NEMA ST20 test methods.
8. Efficiency Curves
    a. Linear Loads
    b. Data per the non-linear load test program.

1.4 STANDARDS

A. Transformers 1000kVA and smaller shall be listed by Underwriters Laboratories.

B. Conform to the requirements of ANSI/NFPA 70.

C. Transformers are to be manufactured and tested in accordance with NEMA ST20.

D. Efficiency – Per DOE 10 CFR 431.192 April 2013

Prior to January 1, 2016 Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers

Single phase		Three phase	
kVA	Efficiency (%)	kVA	Efficiency (%)
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

After January 1, 2016 Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers

Single phase		Three phase	
kVA	Efficiency (%)[1]	kVA	Efficiency (%)[1]
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.6	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1000	99.28

Note: All efficiency values are at 35 percent of nameplate-rated load, determined according to the DOE Test Method for Measuring the Energy Consumption of Distribution Transformers under Appendix A to Subpart K of 10 CFR part 431.

E. CSA 802.2-00 Minimum Efficiency Values for Dry Type Transformers

Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers			
Single phase		Three phase	
kVA	Efficiency (%)	kVA	Efficiency (%)
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

Note: All efficiency values are at 35 percent of nameplate-rated load,

F. Seismic Standards

1. International Building Code (IBC), 2006 ICC Edition.

2. Tri-axial shake table test results conducted in accordance with the AC156 test protocol3 (Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components)

G. International Standards Organization (ISO)

1. ISO 9001:2000 – Quality Management System

2. ISO 14001:2004 – Environmental Management System

1.5 PACKAGING FOR SHIPMENT

A. Transformers shall be packaged for shipment using materials that will have the least environmental impact.

1. Transformer Wrapping

a. Transformers shall be protected by Cardboard protective material – all plastic wraps will not be accepted.

2. Transformer Shipping Base

a. Transformers shall be shipped on a base that uses at least 50% less wood than traditional pallets.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Transformers shall be as manufactured by Square D Company or approved equal.

B. Approved manufacturers shall be registered firms in accordance with ISO 9001:1994 SIC 3612 (US); which is the design and manufacture of low voltage dry type power, distribution and specialty transformers.

2.2 RATINGS INFORMATION

A. All insulating materials are to exceed standards and be rated for 220°C UL component recognized insulation system.

B. Transformers 15kVA and larger shall be 150°C temperature rise above 40°C ambient.

1. Optional Temperature Rise 80°C Rise

C. The maximum temperature of the top of the enclosure shall not exceed 50°C rise above a 40°C ambient.

D. The transformer(s) shall be rated as indicated in the following schedule:

Identification Number(s)
kVA Rating
Voltages
Phase
Frequency

2.3 CONSTRUCTION

A. Transformer coils shall be of the continuous wound construction and shall be impregnated with non-hygroscopic, thermosetting varnish.

B. All cores to be constructed with low hysteresis and eddy current losses. Magnetic flux densities are to be kept well below the saturation point to prevent core overheating.

C. The completed core and coil shall be bolted to the base of the enclosure but isolated by means of rubber vibration-absorbing mounts. There shall be no metal-to-metal contact between the core and coil and the enclosure except for a flexible safety ground strap. Sound isolation systems requiring the complete removal of all fastening devices will not be acceptable.

D. The core of the transformer shall be visibly grounded to the enclosure by means of a flexible grounding conductor sized in accordance with applicable UL and NEC standards.

E. All terminals, including those for changing taps, must be readily accessible by removing a front cover plate.

F. Taps shall have a 5% FCAN and 10% FCBN.

1. 2.5% Steps On all voltages 350 V and above

a. 15 to 225kVA

b. 300kVA

(1) 150°C Rise

(2) 80°C Rise change to 5% FCBN instead of 10%

c. 500 and 750kVA range change to 5% FCBN instead of 10%

d. 1000kVA and greater per Manufacture Design

2. 5% Steps On all voltages below 350 V

a. 15 to 225kVA

b. 300kVA

(1) 150°C Rise

(2) 80°C Rise change to 5% FCBN instead of 10%

c. 500 and 750kVA range change to 5% FCBN instead of 10%

d. 1000kVA and greater per Manufacture Design

G. Transformers shall have provisions for Bonding Neutral to Ground.

H. Transformers ventilated OPENS shall not be located in wire access areas defined on Drawings.

I. Transformer access areas shall allow for NEC bending radius for the following cable ranges by kVA:

kVA	Entering Bottom Access Point Wire Range Bending Space 480V / 600V	Entering Side Access Point Wire Range Bending Space 480V / 600V	Entering Bottom Access Point Wire Range Bending Space 208V / 240V	Entering Side Access Point Wire Range Bending Space 208V / 240V
15	(1) #14-#2AWG	(1) #14-#2/0 AWG	(1) #14-#2AWG	(1) #14-#2/0 AWG
30	(1) #14-#2AWG	(1) #14-#2/0 AWG	(1) #14-#3/0 AWG	(1) #14-250kcmil
45	(1) #14-#2/0 AWG	(1) #14-500kcmil	(1 or 2) #6-#4/0 AWG	(1) #6-500kcmil (2) #6 - 250kcmil
75	(1) #14-#4/0 AWG	(1) #14-500kcmil	(1 or 2) 1/0 - 500kcmil	(1 or 2) 1/0 - 500kcmil
112.5	(1 or 2) #6-#4/0 AWG	(1) #6-500kcmil (2) #6 - 250kcmil	(2) 2/0 - 500kcmil (3) 2/0 - 400kcmil	(2 or 3) 2/0 - 500kcmil
150	(1 or 2) #4 - 350kcmil	(1 or 2) #4 - 500kcmil	(2) 2/0 - 500kcmil (4) 2/0 - 250kcmil (3) 2/0 - 400kcmil	(2, 3 or 4) 2/0 - 500kcmi
225	(1 or 2) 3/0 - 500kcmil	(1 or 2) 3/0 - 500kcmil	(4) 2/0 - 500kcmil	(4) 3/0 - 500kcmil
300	(2) 2/0 - 500kcmil (3) 2/0 - 400kcmil	(2 or 3) 2/0 -500kcmil	(6) 2/0 - 500kcmil	(6) 3/0 - 600kcmil

500	(4) 2/0 - 500kcmil	(4) 3/0 - 500kcmil	(9) 2/0 - 500kcmil	(9) 3/0 - 600kcmil
750	(6) 2/0 - 500kcmil	(6) 3/0 - 600kcmil	(15) 2/0 - 500kcmil	(15) 3/0 - 600kcmil

J. Terminals shall be size to handle cables for the following wire range:

	480 / 600 V		208 / 240 V	
kVA	Terminal Mechanical Lugs	Terminal Compression Lugs NEMA TWO HOLE	Terminal Mechanical Lugs	Terminal Compression Lugs NEMA TWO HOLE
15	2/0-14 AWG	(1) #12-10 AWG (1) #8-#1/0 AWG	2/0-14 AWG	(1) #8-#1/0 AWG
30	2/0-14 AWG	(1) #8-#1/0 AWG	350 kcmil-6 AWG	(1) #8-#1/0 AWG (1) #4-300kcmil (1) 250kcmil-350kcmil
45	2/0-14 AWG 350 kcmil-6 AWG	(1) #8-#1/0 AWG (1) #4-300kcmil	350 kcmil-6 AWG (1) 600 kcmil-4 AWG or (2) Equal 250 kcmil-1/0 AWG	(1) 250kcmil-350kcmil (1) #2/0-500kcmil (2) #4-300kcmil
75	2/0-14 AWG 350 kcmil-6 AWG	(1) #8-#1/0 AWG (1) #4-300kcmil (1) 250kcmil-350kcmil	(1) 600 kcmil-4 AWG or (2) Equal 250 kcmil-1/0 AWG	(2) #2/0-500kcmil (1) 400kcmil-600kcmil (AL) (2) #4-300kcmil (2) 250kcmil-350kcmil
112.5	350 kcmil-6 AWG (1) 600 kcmil-4 AWG or (2) Equal 250 kcmil-1/0 AWG	(1) 250kcmil-350kcmil (1) #2/0-500kcmil (2) #4-300kcmil	(2) 350 kcmil-6 AWG (2) 600 kcmil-2 AWG	(3) 250kcmil-350kcmil (3) #4-300kcmil (2) 400kcmil-600kcmil(AL)
150	(1) 600 kcmil-4 AWG or (2) Equal 250 kcmil-1/0 AWG	(1) 250kcmil-350kcmil (2) #4-300kcmil	(3) 350 kcmil-6 AWG (2) 600 kcmil-2 AWG	(3) #2/0-500kcmil (3) #4-300kcmil (3) 400kcmil-600kcmil(AL) (4) 250kcmil-350kcmil
225	(1) 600 kcmil-2 AWG (2) 600 kcmil-2 AWG	(2) #2/0-500kcmil (2) 400kcmil-600kcmil (AL) (2) #4-300kcmil	(3) 600 kcmil-2 AWG	(4) #4-300kcmil (4) #2/0-500kcmil
300	(2) 600 kcmil-2 AWG	(3) 250kcmil-350kcmil (3) #2/0-500kcmil (3) 400kcmil-600kcmil(AL)	(4) 600 kcmil-2 AWG	(6) #2/0-500kcmil (6) 400kcmil-600kcmil(AL)
500	(3) 600 kcmil-2 AWG	(4) #4-300kcmil (4) #2/0-500kcmil	(6) 600 kcmil-2 AWG	(9) #2/0-500kcmil (9) 400kcmil-600kcmil(AL)
750	(4) 600 kcmil-2 AWG	(6) #2/0-500kcmil (6) 400kcmil-600kcmil(AL)	(9) 600 kcmil-2 AWG	(15) #2/0-500kcmil (15) 400kcmil-600kcmil(AL)

K. The transformer enclosures shall be ventilated and be fabricated of heavy gauge, sheet steel construction. The entire enclosure shall be finished utilizing a continuous process consisting of degreasing, cleaning and phosphatizing, followed by electrostatic deposition of polymer polyester powder coating and baking cycle to provide uniform coating of all edges and surfaces. The coating shall be UL recognized for outdoor use. The coating color shall be ANSI 49.

1. Minimum Clearance from Rear and Sides ½"
2. Units 75kVA and smaller shall have KITS to convert to wall mounted.
3. Units 150kVA and small shall have provisions to be Trapeze Mounted.
4. All enclosures shall have KIT to convert from Type 2 to Type 3R.

2.4 SOUND LEVELS

A. Sound levels shall be warranted by the manufacturer not to exceed the following:

1. 15 to 50kVA – 45dB; 51 to 150kVA – 50dB; 151 to 300 kVA – 55 dB; 301 to 500kVA – 60dB;

2. 501 to 700 kVA – 62 dB; 701 to 1000 kVA – 64dB; 1001 to 1500 kVA – 65dB;

3. 1501 to 2000kVA – 66dB

2.5 OPTIONAL ACCESSORIES

Not Used

PART 3 EXECUTION

3.1 INSTALLATION

A. Not used

END OF SECTION

SECTION 16280 – SURGE PROTECTIVE DEVICES

PART 1 - GENERAL

1.01 REQUIREMENTS

A. The Contractor shall furnish, install, and place in satisfactory operation, the surge protective devices (SPD) as specified herein.

B. Surge protective devices shall be provided as a stand-alone unit, separate from the enclosure of the equipment to which they are connected or as integrally mounted devices as noted on the Contract Drawings.

1.02 CODES AND STANDARDS

A. The surge protective device shall be designed, manufactured, and listed to the following standards:

1. Underwriters Laboratories, Inc. (UL)

   a. UL1449 3rd Edition: Surge Protective Devices

   b. UL1283 5th Edition: Electromagnetic Interference Filters

2. American National Standards Institute (ANSI)/Institute of Electrical & Electronic Engineers (IEEE)

   a. C62.41.1: 2002 Guide for Surge Voltages in Low-Voltage AC Power Circuits

   b. C62.41.2: 2002 Recommend Practice on Characterization of Surges in Low Voltage (100V and Less) AC Power Circuits.

   c. C62.45: 2002 IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000V and Less) AC Power Circuits

   d. C62.62: 2000 IEEE Standard Test Specifications for Surge Protective Devices for Low Voltage (1000V and Less) AC Power Circuits

3. National Electric Code (NEC), Latest Edition

1.03 TESTING

A. All tests shall be performed in accordance with the requirements of the General Conditions and Division 1. The following tests are required:

1. Witnessed Shop Tests

   a. None required.

2. Certified Shop Tests and Reports

   a. Standard factory tests shall be performed on the equipment under this section. All tests shall be in accordance with the latest version of NEMA, ANSI, and UL standards.

   b. All surge protective devices, subassemblies, and components shall be 100% tested and certified by the manufacturer to meet their published performance parameters.

3. Field Tests

    a. None required.

1.04 SUBMITTALS

A. The Contractor shall obtain from the equipment manufacturer and submit the following per Section 01300:

1. Shop Drawings

2. Operation and Maintenance Manuals

3. Spare Parts List

4. Special Tools List

5. Reports of ShopTests

1.05 SHOP DRAWINGS

A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.

B. Partial, incomplete, or illegible submittals will be returned to the Contractor without review for re-submittal.

C. Drawings submitted by the manufacturer shall be complete and documented to provide the Owner with operations and maintenance capabilities.

D. Shop drawings for each SPD shall include but not be limited to:

1. Product Data Sheets.

2. Detailed drawings showing weights and dimensions.

3. Wiring diagrams showing field connections.

4. Proof that all products provided under this Section are UL listed and labeled by Underwriters Laboratories to UL1449 3rd Edition. This proof shall be a copy of the data listed under the UL File Number for the manufacturer, which may be obtained from the UL Online Certification Directory. No other means of proving compliance (such as manufacturer data sheets, marketing material, etc) will be considered acceptable.

5. Proof of Short Circuit Current Ratings (SCCR), Voltage Protection Ratings (VPRs) for all modes, Maximum Continuous Operating Voltage rating (MCOV), Nominal Discharge Current (In), and device listing Type shall be submitted using the same means as described in the paragraph above.

6. Proof that all products provided under this Section are UL listed and labeled by Underwriters Laboratories to UL 1283 5th Edition. This proof shall be a copy of the data listed under the UL File Number for the manufacturer, which may be obtained from the UL Online Certification Directory. No other means of proving compliance (such as manufacturer data sheets, marketing material, etc) will be considered acceptable.

7. Warranty Information

E. The shop drawing information shall be complete and organized in such a way that the Engineer can determine if the requirements of these Specifications are being met. Copies of technical bulletins, technical data sheets from "Soft Cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the Contractor intends to provide are to provide are acceptable and shall be submitted.

1.06 OPERATION AND MAINTENANCE MANUALS

A. The Contractor shall submit operation and maintenance manuals.

1.07 TOOLS, SUPPLIES, AND SPARE PARTS

A. The SPDs and accessories shall be furnished with all special tools necessary to disassemble, service, repair, and adjust the equipment. All spare parts as recommended by the equipment manufacturer shall be furnished by the Contractor to the Owner.

B The Contractor shall furnish one (1) spare field replacement module of each rating provided under this Contract.

C. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.

D. Spare parts shall be delivered at the same time as the equipment to which they pertain. The Contractor shall properly store and safeguard such spare parts until completion of the Work, at which time they shall be delivered to the Owner.

E. Spare parts lists, included with the shop drawing submittal shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.

F. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same part number.

1.08 IDENTIFICATION

A. Each SPD shall be identified by equipment name. A nameplate shall be securely affixed in a conspicuous place on each SPD.

1.09 TRAINING

A. The Contractor shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory trained specialists who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section. The training shall also include an overview of current SPD standards, as well as basic SPD operation and maintenance.

B. Provide the services of an experienced, factory trained technician or service engineer of the SPD manufacturer at the jobsite for minimum of 1/2 day for training of Owner personnel, beginning at a date mutually agreeable to the Contractor and the Owner.

1.10 WARRANTY

A. All SPDs, associated hardware, and supporting components shall be warranted to be free from defects in materials and workmanship, under normal use and in accordance with the instructions provided, for a period of five (5) years after acceptance of the equipment by the Owner.

B. Any component or subassembly contained within the surge protection system that shows evidence of failure or incorrect operation during the five (5) year warranty period, shall be replaced and reinstalled by the manufacturer at no additional cost to the Owner.

PART 2 - PRODUCTS

2.01 GENERAL

A. The SPD shall be UL 1449 3rd Edition Listed and must bear the 3rd Edition mark. Units that are "manufactured in accordance with" UL 1449 3rd Edition or tested by other testing agencies "in accordance with" UL 1449 3rd Edition are not acceptable and will be rejected.

B. The SPD shall be UL 1283 5th Edition Listed and must bear the UL mark. Units that are "manufactured in accordance with" UL 1283 5th Edition or tested by other testing agencies "in accordance with" UL 1283 5th Edition are not acceptable and will be rejected. Further, SPD units using UL 1283 capacitors but not tested to UL 1283 will be rejected.

C. SPDs shall be provided as a stand-alone unit, separate from the equipment to which they are connected.

D. All SPDs furnished and installed under this Contract shall be from the same manufacturer.

2.02 PRODUCTS

A. Type I surge protective devices (SPD) shall be furnished and installed. Type II SPDs are not acceptable.

B. Each SPD shall be rated for the voltage and configuration of the equipment to which it is connected.

C. Each SPD shall have UL 1283 5th Edition EMI/RFI filtering with minimum attenuation of -50dB at 100kHz.

D. The short circuit current rating of each SPD shall match or exceed the rating of the equipment to which it is connected. The Contractor shall reference the Pump Station Schedule for short circuit current rating of each piece of equipment.

E. Each SPD system shall provide surge protection in all possible modes. Surge protection shall be as follows:

SYSTEM CONFIGURATION	MODES OF PROTECTION	NUMBER OF MODES
3-Phase Wye	L-N, L-G, N-G	7
3-Phase Delta	L-L, L-G	6
3-Phase Impedence Grounded	L-L, L-G	6
Single-Phase	L-N, L-G, N-G	3

F. Each SPD shall have a Maximum Continuous Operating Voltage (MCOV) of <u>at least</u> 115% of the nominal voltage of the equipment to which it is connected.

G. The Nominal Discharge Current (I_n) of each SPD shall be 20kA. Peak surge current ratings <u>shall not</u> be used as a basis for applying the SPD to the system.

H. The Voltage Protection Rating (VPR) of each SPD shall not exceed the following:

SYSTEM VOLTAGE	L-N	L-G	L-L	N-G
208Y/120	700V	700V	1200V	700V
480Y/277	1200V	1200V	1800V	1200V
480 DELTA	N/A	1200V	2000V	N/A
240 DELTA	N/A	1200V	1200V	N/A
120/240	700V	700V	1200V	700V

I. The surge current rating for each SPD shall be as indicated on the Contract Drawings. Surge current rating indicated is on a per phase basis.

J. Each SPD shall be provided in an enclosure to match or exceed the NEMA rating of the equipment enclosure that it is serving (i.e. NEMA1, NEMA 12, NEMA 4X, etc).

K. Each SPD shall be provided with the following accessories:

1. Each individual module shall feature an LED indicating the individual module has all surge protection devices active. If any single component is taken off-line, the LED shall turn off and another LED shall illuminate, providing individual module as well as total system status indication.

2. Surge counter and audible alarm with reset/silence switch.

3. One set of Form C (SPDT) dry contacts rated for at least 5A at 120VAC.

L. SPDs shall be as manufactured by Eaton Electrical, Thor Systems, Advanced Protection Technologies (APT), or LEA International.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The SPD units shall be furnished and installed in accordance with the manufacturer's installation instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

B. The SPD units shall be mounted such that the conductor lengths are as short as possible, but no greater than 36 inches. Any installation resulting in a conductor length of greater than 36 inches shall be reviewed with the Engineer as a special type of cable may need to be installed. For equipment such as panelboards, the Contractor shall relocate the circuit breaker that is to be connected to the SPD as needed to achieve the shortest conductor length possible.

C. The Contractor shall use a close nipple to enclose the conductors between the SPD and the equipment served. However, if due to field conditions a 90 degree conduit bend is required to connect the SPD to the equipment that it serves, the bend shall have a minimum radius of 36 inches to eliminate any potential for sharp bends in the conductors.

D. Conductors between the equipment served and the SPD shall be 600V power wire and cable as specified in Section 16120 – Conductors and Cables. The individual conductors shall be gently twisted.

E. Prior to energizing, the Contractor shall verify that the SPD unit voltage and configuration is suitable for the system to which it is connected.

F. Prior to energizing, the Contractor shall also verify that any Neutral to Ground bonding jumpers are installed as required.

G. Prior to energizing, the Contractor shall also verify that the impedence of the equipment grounding conductor between the SPD and the grounding electrode system is less than 1 ohm.

END OF SECTION

SECTION 16315 - PRIMARY GROUNDING

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Grounding shall conform to applicable requirements in the NEC and NESC and as written elsewhere in these Specifications. Neutral conductors, cable shields, metallic conduits, termination bodies, junction boxes, lightning arrestors, fences and all non-current carrying metallic parts of equipment, shall be grounded. Ground rods shall be copper or copper-clad steel, 3/4 inch minimum diameter, at least 10 feet long, driven fully into the earth.

B. Grounding electrodes at transformers and sectionalizing switches shall have a ground resistance not to exceed 5 ohms. Ground resistance shall be measured not less than 48 hours after rainfall. A bare copper cable not smaller than No. 4/0 AWG shall be installed not less than 30 inches below grade connecting to the indicated ground rods. Fence and equipment connections shall not be smaller than No. 4 AWG. Transformer neutral connections shall not be smaller than 1/0 AWG. Where rated secondary current exceeds 400 amperes, the size of the neutral ground connection shall be increased to not less than 2 of the area of secondary phase conductors. Where measured ground resistance exceeds 5 ohms, additional rods shall be driven, not less than 10 feet apart, connected with 4/0 cable, until proper resistance is achieved (50 foot total rod length maximum).

C. All concealed or buried grounding system connections or grounding electrode connection shall be of the exothermic weld type.

D. Lightning arrestor grounding conductors shall be separate from other grounding conductors, but shall be bonded to the neutral or to the equipment ground where such ground exists within 50 feet.

E. All grounding electrodes at transformers and lightning arrestors shall be tested for conformance to the 5 ohm value and the procedure shall be the same as described in Section 16060 on secondary grounding.

F. Fences shall be grounded at every gatepost and corner post and additionally at spacing's between corner posts and/or gate posts not to exceed 160 feet. Each gate section shall be bonded to the fencepost with a flexible braided copper grounding strap.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION (NOT USED)

END OF SECTION

SECTION 16370 - OVERHEAD MEDIUM VOLTAGE POWER DISTRIBUTION

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. This specification covers the requirements for aerial electrical distribution systems using wood poles.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. See Electrical Section 16050, Basic Electrical Materials & Methods for general requirements relating to electrical work performer under this contract.

B. See Electrical Section 16315, Primary Grounding for grounding of aerial electrical distribution systems.

1.03 SUBMITTALS

A. Catalog cuts, brochures, circulars, specifications, product data, and printed information in sufficient detail and scope to verify compliance with the requirements of the contract documents shall be submitted.

B. A complete itemized listing of equipment and materials proposed for incorporation into the work shall be submitted. Each entry shall include the item number, the quantity of items proposed, and the name of the manufacturer of the item.

C. Detail drawings consisting of equipment drawings, illustrations, schedules, instructions, diagrams and other information necessary to define the installation and enable the Owner to check conformity with the requirements of the Contract Drawings shall be submitted. Detail drawings shall as a minimum include:

1. Poles
2. Crossarms and braces
3. Transformers
4. Conductors
5. Insulators
6. Surge arrestors
7. Fused cutouts
8. Hardware
9. Line tension switches

If departures from the Contract Drawings are deemed necessary by the Contractor, complete details of such departures shall be submitted with the detail drawings. Accepted departures shall be made at no additional cost to the Owner.

D. Detail drawings shall show how components are assembled, function together and how they will be installed on the project. Data and drawings for component parts of an item or system shall be coordinated and submitted as a unit. Data and drawings shall be coordinated and included in a single submission. Detail drawings shall consist of the following:

1. Detail drawings showing physical arrangement, construction details, connections, finishes, materials used in fabrication, provisions for conduit or busway entrance, access requirements for installation and maintenance, physical size, electrical characteristics, foundation and support details, and equipment weight. Drawings shall be drawn to scale and/or dimensioned. Optional items shall be clearly identified as included or excluded.

2. Internal wiring diagrams of equipment showing wiring as actually provided for this project. External wiring connections shall be clearly identified.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Devices and equipment shall be visually inspected by the Contractor when received and prior to acceptance from conveyance. Stored items shall be protected from the environment in accordance with the manufacturer's published instructions. Damaged items shall be replaced. Oil-filled transformers and switches shall be stored in accordance with the manufacturer's requirements. Wood poles held in storage for more than 2 weeks shall be stored in accordance with ANSI Standards. Handling of wood poles shall be in accordance with ANSI Standards, except that pointed tools capable of producing indentations more than inch in depth shall not be used.

1.05 EXTRA MATERIALS

A. One additional spare fuse or fuse element for each furnished fuse or fuse element shall be delivered to the Owner when the electrical system is accepted. Two complete sets of all special tools required for maintenance shall be provided, complete with a suitable tool box. Special tools are those that only the manufacturer provides, for special purposes (to access compartments, or operate, adjust, or maintain special parts).

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Products shall conform to the following requirements. Items of the same classification shall be identical, including equipment, assemblies, parts, and components.

2.02 STANDARD PRODUCT

A. Material and equipment shall be the standard product of a manufacturer regularly engaged in the manufacture of the product and shall essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening.

2.03 NAMEPLATES

A. General

1. Each major component shall have the manufacturer's name, address, type or style, model or serial number, and catalog number on a nameplate securely attached to the equipment. Equipment containing liquid-dielectrics shall have the type of dielectric on the nameplate. Nameplates shall be made of non-corrosive metal. As a minimum, nameplates shall be provided for transformers, regulators, circuit breakers, capacitors, meters and switches.

2.04 CORROSION PROTECTION

A. Aluminum Materials

1. Aluminum shall not be used in contact with earth or concrete. Where aluminum conductors are connected to dissimilar metal, fittings conforming to UL Standards shall be used.

B. Ferrous Metal Materials

1. Hardware

a. Ferrous metal hardware shall be hot-dip galvanized in accordance with ASTM Standards.

2. Equipment

a. Equipment and component items shall be provided with corrosion-resistant finishes which shall withstand 120 hours of exposure to the salt spray test specified in ASTM Standards without loss of paint or release of adhesion of the paint primer coat to the metal surface in excess of 1.6mm (1/16 inch) from the test mark. Cut edges or otherwise damaged surfaces of hot-dip galvanized sheet steel or mill galvanized sheet steel shall be coated with a zinc rich paint conforming to the manufacturer's standard.

3. Finishing

a. Painting required for surfaces not otherwise specified and finish painting of items only primed at the factory shall be field painted.

2.05 CONDUCTORS, CONNECTORS, AND SPLICES

A. Aluminum-Composition Conductors

1. Aluminum-conductor-Class B stranded shall comply with ASTM Standards.

B. Connectors and Splices

1. Connectors and splices shall be of copper alloys for copper conductors, aluminum alloys for aluminum-composition conductors, and a type designed to minimize galvanic corrosion for copper to aluminum-composition conductors.

2.06 MEDIUM-VOLTAGE LINES

A. 15kV Medium-Voltage Lines

1. Medium-voltage line conductors shall be insulated, multi-conductor, self-supporting, 133% insulation level, EPR aluminum-conductor, as indicated on the Drawings. Provide copper clad steel or stainless steel messenger cable and stainless steel strapping.

2.07 LOW-VOLTAGE LINES

A. Low-voltage line conductors shall be of the neutral-supported secondary and service drop type with cross-linked thermosetting polyethylene (XLP) insulation. Neutral-supported secondary and service drop conductors shall be insulated copper with bare hard-drawn-copper or copper-clad steel neutrals or insulated aluminum with bare 1350 alloy aluminum or ASCR neutrals, as indicated on the Drawings or to match existing.

2.08 POLES AND HARDWARE

A. Poles shall be of lengths and classes/strengths indicated.

B. Wood Poles

1. Wood poles shall comply with ANSI Standards and shall be pressure treated in accordance with AWPA, with pentachlorophenol preservatives conforming to AWPA P5. Wood poles shall have pole markings located approximately 3m (10 feet) from pole butts for poles 15.2m (50 feet) or less in length, and 4m (14 feet) from the pole butts for poles longer than 16.8m (55 feet) in length. Poles shall be machine trimmed by turning smooth full length, and shall be

roofed, gained, and bored prior to pressure treatment. Where poles are not provided with factory-cut gains, metal gain plates shall be provided. Poles preserved with creosote or CCA are prohibited.

C. Pole Line Hardware

1. Zinc-coated hardware shall comply with ANSI C135.1, ANSI C135.2, ANSI C135.4, ANSI C135.14, ANSI C135.17, ANSI C135.22, and ANSI C135.33. Steel hardware shall comply with ASTM A 575 and ASTM A 576. Hardware shall be hot-dip galvanized in accordance with ASTM A 153. Pole-line hardware shall be hot-dip galvanized steel. Washers shall be installed under boltheads and nuts on wood surfaces and elsewhere as required. Washers used on through-bolts and double-arming bolts shall be approximately 57.2mm square (2 1/4 inches square) and 4.8mm (3/16 inches) thick. The diameter of holes in washers shall be the correct standard size for the bolt on which a washer is used. Washers for use under heads of carriage-bolts shall be of the proper size to fit over square shanks of bolts. Eye bolts, bolt eyes, eyenuts, strain-load plates, lag screws, fasteners, hooks, shims, and clevises shall be used wherever required to support and to protect poles, brackets, crossarms, guy wires, and insulators.

D. Guy Assemblies

1. Guy assemblies shall be zinc-coated steel in accordance with ASTM A 475. Guy assemblies, including insulators and attachments, shall provide a strength exceeding the required guy strength. Three-eye thimbles shall be provided on anchor rods to permit attachment of individual primary, secondary, and communication down guys. Anchors shall provide adequate strength to support all loads. Guy strand shall be 7 strand. Guy material shall be Class A zinc-coated-steel high-strength grade, with a minimum breaking strength no less than 10,000 pounds, except where two of more guys are used to provide the required strength. Guy rods shall be not less than 8 feet in length by 3/4 inch in diameter. See Drawings for other sizes used.

2.09 INSULATORS

A. Insulators shall comply with NEMA HV 2 for general requirements. Suspension insulators shall be used at corners, angles, dead-ends, other areas where pin insulators do not provide adequate strength, and as indicated. Mechanical strength of suspension insulators and hardware shall exceed the rated breaking strength of the attached conductors.

B. Medium-Voltage Line Insulators

1. Medium-voltage line insulators shall comply with ANSI C29.2, ANSI C29.5, and ANSI C29.6 as applicable. Ratings shall not be lower than the ANSI classes indicated in Table I. Pin insulators shall be used for crossarm construction. Pin insulators for use on voltages in excess of 6 kV phase-to-phase shall be radio-interference-freed.

Table I - Minimum ANSI Rating Of Medium-Voltage Insulators By Class		
Voltage Level	**Pin**	**Suspension**
6 kV to 15 kV	55-2	Two 52-2
26 kV to 35 kV	56-4	Three 52-3 or 4

C. Low-Voltage Line Insulators

1. Low-voltage line insulators shall comply with ANSI C29.2 and ANSI C29.3 as applicable. Spool insulators for use on low-voltage lines shall be mounted on clevis attachments and shall be not smaller than Class 53-2. For No. 4/0 AWG and larger conductors, Class 53-4 shall be used. Suspension insulators on clevis attachments used at dead-ends shall not be smaller than Class 52-1.

D. Strain Insulators for Guy Wires

1. Strain insulators for use in insulated guy assemblies shall comply with ANSI C29.4 for porcelain or equivalent fiberglass, and shall have a mechanical strength exceeding the rated breaking strength of the attached guy wire. Insulators shall be not smaller Class 54-2 for lines of 6 kV to 15 kV (12,000 pounds tensile strength).

2.10 CROSSARM ASSEMBLIES

A. Crossarms

1. Crossarms shall comply with REA Bulletin 1728H-701 and shall be solid wood, distribution type, except cross-sectional area with pressure treatment conforming to AWPA C25, and a 6.4mm (1/4 inch), 45 degree chamfer on all top edges. Cross-sectional area minimum dimensions shall be 4-5/8 inches in height by 3-5/8 inches in depth in accordance with IEEE C2 for Grade C construction. Other sizes and types may be used. See Drawings. Crossarms shall be 2.4m (8 feet) in length, except that 3.1m (10 foot) crossarms shall be used for crossarm-mounted banked single-phase transformers or elsewhere as indicated. Crossarms shall be machined, chamfered, trimmed, and bored for stud and bolt holes before pressure treatment. Factory drilling shall be provided for pole and brace mounting, for four pin or four vertical line-post insulators, and for four suspension insulators, except where otherwise indicated or required. Drilling shall provide required climbing space and wire clearances. Crossarms shall be straight and free of twists to within 2.5mm per 304.8mm (1/10 inch per foot) of length. Bend of twist shall be in one direction only.

B. Crossarm Gains

1. Crossarm gains shall comply with ANSI C135.33.

2.11 FUSES AND SWITCHES, MEDIUM-VOLTAGE

A. Fuse Cutouts

1. Medium-voltage fuses and cutouts shall comply with NEMA SG 2 and shall be of the load break, open type construction, rated 7.8 kV and of the ratings and types indicated. Open-link cut-outs are not acceptable. Fuses shall be either indicating or dropout type. Fuse ratings shall be as indicated. Fuse cutouts shall be equipped with mounting brackets suitable for the indicated installations.

B. Nonfused Switches

1. Nonfused switches shall be single-pole, manual devices with a continuous current rating of 600 amperes rms, a momentary asymmetrical current rating of 40 kA rms, and shall be rated for 15 kV. Units shall be crossarm mount type or line tension as shown in the Drawings.

2.12 TRANSFORMERS

A. Refer to specification Section 16270 and the Drawings.

2.13 SURGE ARRESTORS

A. Surge arrestors shall comply with NEMA LA 1 and IEEE C62.1, IEEE C62.2, and IEEE C62.11, and shall be provided for protection of aerial-to-underground transitions, transformers and other indicated equipment. Arrestors shall be heavy-duty distribution class, rated 3 kV. Arrestors shall be equipped with mounting brackets suitable for the indicated installations. Arrestors shall be of the combination valve-metal-oxide varistor type suitable for outdoor installations.

2.14 GROUNDING AND BONDING

A. Driven Ground Rods

1. Ground rods shall be of copper-clad steel not less than 19.1mm (3/4 inch) in diameter by 3.1 meter (10 feet) in length of the sectional type driven full length into the earth.

B. Grounding Conductors

1. Grounding conductors shall be bare copper, except where installed in conduit with associated phase conductors. Insulated conductors shall be of the same material as the phase conductors and green color-coded, except that conductors shall be rated no more than 600 volts. Bare conductors shall be soft-drawn unless otherwise indicated. Aluminum is not acceptable. Minimum size #6.

PART 3 - EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Equipment and devices shall be installed and energized in accordance with the manufacturer's published instructions.

B. Conformance to Codes

1. The installation shall comply with the requirements and recommendations of IEEE C2 for heavy loading district, Grade C construction. No reduction in clearance shall be made. The installation shall also comply with the applicable parts of NFPA 70.

C. Verification of Dimensions

1. The Contractor shall become familiar with details of the work, shall verify dimensions in the field, and shall notify the Owner of any discrepancy before performing any work.

D. Tree Trimming

1. Where lines pass through trees, trees shall be trimmed at least 4.5 m (15 feet) clear on both sides horizontally and below for medium-voltage lines, and 1.5 m (5 feet) clear on both sides horizontally and below for other lines, and no branch shall overhang horizontal clearances.

3.02 POLE INSTALLATION

A. Joint-use electric/roadway-lighting poles for overhead electric and communication lines shall be wood poles utilizing crossarm construction. Cluster-mounted banked single-phase transformer installations shall be provided. Crossarm construction shall be provided for support of other equipment, except where direct-pole mounting is indicated. Provision for communication services is required on pole-line construction, except where specifically noted otherwise. A vertical pole space shall be reserved at all locations.

B. Wood Pole Setting: Wood poles shall be set straight and firm. In normal firm ground, minimum pole-setting depths shall be as listed in Table II. In rocky or swampy ground, pole-setting depths shall be decreased or increased respectively in accordance with the local utility's published standards and as approved. Poles in straight runs shall be in a straight line. Curved poles shall be placed with curvatures in the direction of the pole line. Poles shall be set to maintain as even a grade as practicable. When the average ground run is level, consecutive poles shall not vary more than 1.5 m (5 feet) in height. When the ground is uneven, poles differing in length shall be kept to a minimum by locating poles to avoid the highest and lowest ground points. If it becomes necessary to shorten a pole, a piece shall be sawed off the top end and roofed. If any pole is shortened after treatment, the shortened end of the pole shall be given an application of hot preservative. Where poles are set on hilly terrain, along edges of cuts or embankments, or where soil may be washed out, special precautions shall be taken to ensure durable pole foundations, and the setting depth shall be measured from the lower side of the pole. Holes shall be dug large enough to permit proper use of tampers to the full depth of a hole. Earth shall be placed into the hole in 300 mm (6 inch) maximum layers, then thoroughly tamped before the next layer is placed. Surplus earth shall be placed around each pole in a conical shape and packed tightly to drain water away from poles.

Table II - Minimum Pole Setting Depth (Meters)

Length Overall (Meters)	Straight Lines	Curves, Corners, and Points of Extra Strain
7.6	1.7	1.7
9.2	1.7	1.7
10.7	1.8	1.8
12.2	1.8	1.8
13.7	2.0	2.1
15.2	2.1	2.3
16.7	2.3	2.5
18.3	2.5	2.6
19.8	2.6	2.6
21.3	2.8	2.9
22.9	2.9	3.0
24.4	3.0	3.2
25.9	3.2	3.3
27.4	3.3	3.5
28.9	3.5	3.7
30.5	3.7	3.8

Table II - Minimum Pole-Setting Depth (Feet)		
Length Overall (Feet)	**Straight Lines**	**Curves, Corners, and Points of Extra Strain**
20	5.0	5.0
25	5.5	5.5
30	5.5	5.5
35	6.0	6.0
40	6.5	6.5
45	6.5	7.0
50	7.0	7.5
55	7.5	8.0
60	8.0	8.5
65	8.5	9.0
70	9.0	9.5
75	9.5	10.0
80	10.0	10.5
85	10.5	11.0
90	11.0	11.5
95	11.5	12.0
100	12.5	12.5

3.03 CROSSARM MOUNTING

A. Crossarms shall be bolted to poles with 15.9 m (5/8 inch) through-bolts with square washers at each end. Bolts shall extend not less than 3 mm (1/8 inch) nor more than 50 mm (2 inches) beyond nuts. On single crossarm construction, the bolt head shall be installed on the crossarm side of the pole. Metal or wood crossarm braces shall be provided on crossarms. Flat braces may be provided for 2.4 m (8 foot) crossarms and shall be 6.4 by 31.8 mm (1/4 by 1-1/4 inches), not less than 700 mm (28 inches) in length. Flat braces shall be bolted to arms with 9.5 mm (3/8 inch) carriage bolts with round or square washers between boltheads and crossarms, and secured to poles with 50.8 by 101.6 mm (2 by 4 inch) lag screws after crossarms are leveled and aligned. Angle braces are required for 3.1 m (10 foot) crossarms and shall be 1.5 m (60 inch) span by 457.2 mm (18 inch) drop formed in one piece from 38.1 by 38.1 by 4.8 mm (1-1/2 by 1-1/2 by 3/16 inch) angle. Angle braces shall be bolted to crossarms with 50.8 mm (2 inch) bolts with round or square washers between boltheads and crossarms, and secured to poles with 15.9 mm (5/8 inch) through-bolts. Double crossarms shall be securely held in position by means of 15.9 mm (5/8 inch) double-arming bolts. Each double-arming bolt shall be equipped with four nuts and four square washers.

B. Line arms and buck arms shall be set at right angles to lines for straight runs and for angles 45 degrees and greater; and line arms shall bisect angles of turns of less than 45 degrees. Dead-end assemblies shall be used for turns where shown. Buckarms shall be installed, as shown, at corners and junction poles. Double crossarms shall be provided at ends of joint use or conflict sections, at dead-ends, and at angles and corners to provide adequate vertical and longitudinal strength. Double crossarms shall be provided at each line-crossing structure and where lines not attached to the same pole cross each other.

C. Equipment arms shall be set parallel or a right angles to lines as required to provide climbing space. Equipment arms shall be located below line construction to provide necessary wire and equipment clearances.

3.04 GUY INSTALLATION

A. Guys shall be provided where shown, with loads and strengths as indicated, and wherever conductor tensions are not balanced, such as at angles, corners, and dead-ends. Where a single guy will not provide the required strength, two or more guys shall be provided. Approved guy grips shall be provided at each guy terminal. Guy-strain insulators shall be provided in each guy for wood poles. Rock anchors shall be installed in rock at right angles to guys, elsewhere anchors shall be of an expanding type, except that power installed screw anchors of equivalent holding power are acceptable. A half-round yellow polyvinyl, fiberglass, or other suitable plastic guy marker, not less than 2.4 m (8 feet) in length, shall be provided at the anchor end of each guy shown, securely clamped to the guy or anchor at the bottom and top of the marker. Holding capacities for down guys shall be based on a lead angle of 45 degrees.

3.05 CONDUCTOR INSTALLATION

A. Line Conductors:

1. Unless otherwise indicated, conductors shall be installed in accordance with manufacturer's approved tables of sags and tensions. Proper care shall be taken in handling and stringing conductors to avoid abrasions, sharp bends, cuts, kinks, or any possibility of damage to insulation or conductors. Conductors shall be paid out with the free end of conductors fixed and cable reels portable, except where terrain or obstructions make this method unfeasible. Bend radius for any insulated conductor shall not be less than the applicable NEMA specification recommendation. Conductors shall not be drawn over rough or rocky ground, nor around sharp bends. When installed by machine power, conductors shall be drawn from a mounted reel through stringing sheaves in straight lines clear of obstructions. Initial sag and tension shall be checked by the Contractor, in accordance with the manufacturer's approved sag and tension charts, within an elapsed time after installation as recommended by the manufacturer.

B. Connectors and Splices:

1. Connectors and splices shall be mechanically and electrically secure under tension and shall be of the nonbolted compression type. The tensile strength of any splice shall be not less than the rated breaking strength of the conductor. Splice materials, sleeves, fittings, and connectors shall be non-corrosive and shall not adversely affect conductors. Aluminum-composition conductors shall be wire brushed and an oxide inhibitor applied before making a compression connection. Connectors which are factory-filled with an inhibitor are acceptable. Inhibitors and compression tools shall be of types recommended by the connector manufacturer. Primary line apparatus taps shall be by means of hot line clamps attached to compression type bail clamps (stirrups). Low-voltage connectors for copper conductors shall be of the solderless pressure type. Non-insulated connectors shall be smoothly taped to provide a waterproof insulation equivalent to the original insulation, when installed on insulated conductors. On overhead connections of aluminum and copper, the aluminum shall be installed above the copper.

C. Conductor-To-Insulator Attachments

1. Conductors shall be attached to insulators by means of clamps, shoes or tie wires, in accordance with type of insulator. For insulators requiring conductor tie-wire attachments, tie-wire sizes shall be as indicated in Table III.

Table III - Tie-Wire Requirements	
Conductor Copper (AWG)	**Tie Wire Soft-Drawn Copper (AWG)**
6	8
4 and 2	6
1 through 3/0	4
4/0 and larger	2
ACSR (AWG)	**AAAC or AAC (AWG)**
Any Size	6 or 4

D. Armor Rods:

1. Armor rods shall be provided for ACSR conductors. Armor rods shall be installed at supports, except armor rods will not be required at primary dead-end assemblies if aluminum or aluminum-lined zinc-coated steel clamps are used. Lengths and methods of fastening armor rods shall be in accordance with the manufacturer's recommendations. For span lengths of less than 61 m, (200 feet,) flat aluminum armor rods may be used. Flat armor rods shall be not less than 1.3 by 7.6 mm (0.05 by 0.30 inches). For span lengths of 61 m (200 feet) or more, preformed round armor rods shall be used. **In lieu of armor rods, neoprene coated tie wires designed to protect the conductor from abrasion at connections may be used at Contractor's discretion. Such ties shall also provide a conductor pad.**

E. Low-Voltage Insulated Cables

1. Low-voltage cables shall be supported on clevis fittings using spool insulators. Dead-end clevis fittings and suspension insulators shall be provided where required for adequate strength. Dead-end construction shall provide a strength exceeding the rated breaking strength of the neutral messenger. Clevis attachments shall be provided with not less than 15.9 mm (5/8 inch) through-bolts.

3.06 CONNECTIONS TO UTILITY LINES

A. The Contractor shall coordinate the work with Kentucky Utilities, and shall provide for final connections to the utility electric lines.

3.07 CONNECTIONS TO BUILDINGS

A. Aerial Services:

1. Connections to buildings shall be made at approximately the point indicated and shall be connected to the service entrance conductors. Supports at buildings shall be adequate to withstand required pulls; supports shall not be rated less than 4450 N (1000 pounds). Drip loops shall be formed on conductors at entrances to buildings, cabinets, or conduits.

3.08 GROUNDING

A. Noncurrent-carrying metal parts of equipment and conductor assemblies, such as luminaires, medium-voltage cable terminations and messengers, operating mechanisms of pole top switches, panel enclosures, transformers, and other non-current-carrying metal items shall be grounded. Additional grounding of equipment, neutral, and surge arrester grounding systems shall be installed at poles where indicated.

B. Grounding electrodes shall be installed as follows:

1. Driven rod electrodes - unless otherwise indicated, ground rods shall be located approximately 900 mm (3 feet) out from base of the pole and shall be driven into the earth until the tops of the rods are approximately 300 mm (1 foot) below finished grade. Multiple rods shall be evenly spaced at least 3 m (10 feet) apart and connected together 600 mm (2 feet) below grade with a minimum No. 6 bare copper conductor.

2. Pole butt electrodes - Pole butt electrodes shall be installed where indicated, except that this method shall not be the sole grounding electrode at transformer locations. The pole butt electrode shall consist of a coil of at least 4 m (12 feet) of minimum No. 6 bare copper conductor stapled to the butt of the pole.

3. Plate electrodes - Plate electrodes shall be installed in accordance with the manufacturer's instructions and IEEE C2 and NFPA 70.

4. Ground Resistance - The maximum resistance of a driven ground rod shall not exceed 25 ohms under normally dry conditions. Whenever the required ground resistance is not met, provide additional electrodes interconnected with grounding conductors, to achieve the specified ground resistance. The additional electrodes will be up to three, 3 m (10 feet) rods spaced a minimum of 3 m (10 feet) apart. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, the Owner shall be notified. Connections below grade shall be exothermically welded. Connections above grade shall be exothermically welded or shall use UL 467 approved connectors.

C. Grounding and Bonding Connections:

1. Connections above grade shall be made by the exothermically-welding process or with bolted solderless connectors in compliance with UL 467, and those below grade shall be made by the exothermically welding process. Where grounding conductors are connected to aluminum-composition conductors, specially treated or lined copper-to-aluminum connectors suitable for this purpose shall be used.

D. Grounding Electrode Conductors:

1. On multi-grounded circuits, as defined in IEEE C2, provide a single continuous vertical grounding electrode conductor. Neutrals, surge arresters, and equipment grounding conductors shall be bonded to this conductor. For single grounded or ungrounded systems, provide a grounding conductor for the surge arrester and equipment grounding conductors and a separate grounding conductor for the secondary neutrals. Grounding electrode conductors shall be sized as shown. Secondary system neutral conductors shall be connected directly to the transformer neutral bushings, then connected with a neutral bonding jumper between the transformer neutral bushing and the vertical grounding electrode conductor, as shown. Grounding electrode conductors shall be stapled to wood poles at intervals not exceeding 600 mm (2 feet). Bends greater than 45 degrees in grounding electrode conductor are not permitted. Protective molding shall be installed over pole grounding conductors.

3.09 FIELD TESTING

A. General

1. Field testing shall be performed in the presence of the Owner's representative. The Contractor shall notify the Owner two (2) days prior to conducting tests. The Contractor shall furnish materials, labor, and equipment necessary to conduct field tests. The Contractor shall perform tests and inspections recommended by the manufacturer. The Contractor shall maintain a written record of tests which includes date, test performed, personnel involved, devices tested, serial number and name of test equipment, and test results. Field reports will be signed and dated by the Contractor.

B. Safety

1. The Contractor shall provide and use safety devices such as rubber gloves, protective barriers, and danger signs to protect and warn personnel in the test vicinity. The Contractor shall replace any devices or equipment, which are damaged due to improper test procedures or handling.

C. Ground-Resistance Tests

1. The resistance of each grounding electrode system shall be measured using the fall-of-potential method defined in IEEE Std. 81. Ground resistance measurements shall be made before the electrical distribution system is energized and shall be made in normally dry conditions not less than 48 hours after the last rainfall. Resistance measurements of separate grounding electrode systems shall be made before the systems are bonded together below grade. The combined resistance of separate systems may be used to meet the required resistance, but the specified number of electrodes shall be provided.

D. Sag and Tension Test

1. The Owner shall be given prior notice of the time schedule for stringing conductors or cables serving overhead medium-voltage circuits and reserves the right to witness the procedures used for ascertaining that initial stringing sags and tensions are in compliance with requirements for the applicable loading district and cable weight.

E. Low-Voltage Cable Test (Only Required When New Cable Installed.)

1. For service laterals from overhead lines, the low-voltage cable, complete with splices, shall be tested for insulation resistance after the cables are installed, in their final configuration, ready for connection to the equipment, and prior to energization. The test voltage shall be 500 volts dc, applied for one minute between each conductor and ground and between all possible combinations of conductors in the same cable. The minimum value of insulation shall be:

   R in megohms = (rated voltage in kV +1) x 304,800/ (length of cable in meters)

   R in megohms = (rated voltage in kV +1) x 1000/ (length of cable in feet)

2. Each cable failing this test shall be repaired or replaced. The repaired cable shall then be retested until failures have been eliminated.

F. Liquid-Filled Transformer Tests (Required After Temporary Hook-up and After Final Connection to New Line.)

1. The following field tests shall be performed on liquid-filled transformers. Pass-fail criteria shall be in accordance with the transformer manufacturer's specifications.

   a. Correct phase sequence.

G. Pre-Energization Services

1. The following services shall be performed on the equipment listed below. These services shall be performed subsequent to testing but prior to the initial energization. The equipment shall be inspected to ensure that installation is in compliance with the recommendations of the manufacturer and as shown on the detail drawings. Terminations of conductors at major equipment shall be inspected to ensure the adequacy of connections. Bare and insulated conductors between such terminations shall be inspected to detect possible damage during installation. If factory tests were not performed on completed assemblies, tests shall be performed after the installation of completed assemblies. Components shall be inspected for damage caused during installation or shipment and to ensure that packaging materials have been removed. Components capable of being both manually and electrically operated shall be operated manually prior to the first electrical operation. Components capable of being

calibrated, adjusted, and tested shall be calibrated, adjusted, and tested in accordance with the instructions of the equipment manufacturer. Items for which such services shall be provided, but are not limited to, are the following:

Switches.

Cutouts.

H. Operating Tests

1. After the installation is completed, and at such time as the Owner may direct, the Contractor shall conduct operating tests for acceptance. The equipment shall be demonstrated to operate in accordance with the specified requirements.

3.10 ACCEPTANCE

A. Final acceptance of the project will not be given until the Contractor has successfully completed all tests and after all defects in installation, material or operation have been corrected.

END OF SECTION

SECTION 16435 – MEDIUM VOLTAGE SWITCHGEAR

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American National Standards Institute (ANSI):

   a. C37.04, Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

   b. C37.06, Switchgear-AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

   c. C37.09, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

   d. C37.2, Standard Electric Power Systems Device Function Numbers.

   e. C37.20.2, Metal-Clad and Station Type Cubicle Switchgear.

   f. C37.90.1, Standard Surge Withstand Capacity (SWC) Tests for Protective Relays and Relay Systems.

   g. C39.1, Electrical Analog Indicating Instruments, Requirements for.

   h. C39.5, Electrical and Electronic Measuring and Controlling Instrumentation, Safety Requirements.

   i. C57.13, Standard Requirements for Instrument Transformers.

   j. C62.11, Standard for Metal-Oxide Surge Arrestors for AC Power Circuits.

   k. Z55.1, Gray Finishes for Industrial Apparatus and Equipment.

2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

   a. 460, Standard for Electrical Measuring Transducer for Converting AC Electrical Quantities into DC Electrical Quantities.

3. National Electrical Manufacturers Association (NEMA):

   a. LA 1, Surge Arrestors.

   b. SG 4, Alternating-Current High-Voltage Circuit Breakers.

   c. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).

4. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).

5. Uniform Building Code (UBC): Section 2312, Earthquake Requirements.

1.02 SCOPE OF WORK

A. This specification covers the requirements for new medium voltage switchgear and modifications to existing medium voltage switchgear.

B. Applicable sections of this specification shall apply to the modification of the existing medium voltage distribution gear as indicated in the plan set. Contractor will add two fused sections to existing Square-D gear. This work will involve field measurements and documenting existing conditions. Contractor is solely responsible for all aspects of the switchgear modification. New sections to existing gear are to match the housing and enclosure ratings of the existing. Provide new medium voltage proximity voltage detector with Hot Stick and PPE gloves. Provide two complete sets of replacement fuses.

C. New and modified switchgear shall be provided with power quality monitoring cable of determining the direction of disturbances equal to Square-D 7650 and provide associated monitoring software with preconfigured reports.

D. Feeder breakers shall be provided with Square-D 5000 series power quality monitors and associated Ethernet managed switch for all devices.

E. Refer to Section 16437 for neutral resistor monitoring system requirements.

1.03 SUBMITTALS

A. Shop Drawings:

1. Descriptive product information.
2. Dimensional drawings.
3. Itemized bill of material.
4. Protective device time-current characteristics on transparencies.
5. Operational description.
6. Installation instructions.
7. Bus data.
8. One-line, three-line, and control schematic drawings.
9. Connection and interconnection drawings.
10. Conduit entrance locations.
11. Communication drawings for internal and external devices.

B. Quality Control Submittals:

1. Operation and maintenance manual.

1.04 UL COMPLIANCE

A. Products manufactured within scope of Underwriters Laboratories shall conform to UL Standards and have an applied UL listing mark.

B. UL listing mark for Category “A” enclosure requirements of ANSI C37.20.2, Appendix A.

1.05 PACKING AND SHIPPING

A. Shipping Splits: As shown to facilitate ingress of equipment to final installation location within the building.

1.06 SPARE PARTS

A. Furnish, tag, and box for shipment and storage the following spare parts, special tools, and materials:

1. 5 Each-Spare fuse, both power and control, of every size and type used.

2. 15 Each-Switchgear indicating lamps.

3. 2 Each-Indicating lamp pullers.

4. 12 Each-Color caps of each color for indicating lamps.

5. Crank for racking breakers and crank lifting device.

6. Remote racking device and closing mechanism to allow operator to be outside of Arcflash boundry.

7. Remote operator interface terminal to open/close breakers remotely with operator outside of Arcflash boundry.

8. Network switch

9. One of each power monitor and relay used.

PART 2 - PRODUCTS

2.01 GENERAL

A. Furnish switchgear that is the product of a single manufacturer. Assembled units with component parts of several manufacturers will not be acceptable with the exception that such minor items as terminal blocks, test switches, fuses, wiring, etc., may be manufactured by others.

B. Design, test, and assemble in accordance with ANSI C37.04, C37.06, and C37.20.2, IEEE 37.20.7 and NEMA SG4.

C. Suitable for 4800 volts (4.8kV), three-phase, three-wire electrical service having an available short-circuit current of 63 kA.

D. All indicator lights shall be LED type with push to test design, 30 mm.

E. Provide equipment rating such as voltage (max, nominal, etc.) and amps.

2.02 STANDARD PRODUCT

A. Material and equipment shall be the standard product of a manufacturer regularly engaged in the manufacture of the product and shall essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening.

2.03 MANUFACTURERS

A. Square-D

B. Allen Bradley

C. ASCO Power Technologies

D. Russelectric

E. Square D Group Schneider

F. ABB

G. Siemens

H. Equal by Others with Owner Approval.

2.04 STATIONARY STRUCTURE

A. Type: Indoor switchgear consisting of fuse, main and tie breakers, transition, and auxiliary sections assembled to form a rigid, self-supporting, metal enclosed structure.

B. Material: 11-gauge minimum cold-rolled steel, formed with reinforced steel members.

2.05 ENCLOSURE

A. Finish: Baked enamel applied over a rust-inhibiting, phosphated base coating.

1. Color: Match existing color.

B. Indoor Enclosure:

1. NEMA 250, Type 1, with formed edges on hinged panels.

2. Rear, full height, hinged panels for each enclosure section.

3. Cable Termination Access: Padlock provision.

4. All lights shall be LED type.

5. Infrared viewing windows for thermal imager direct line of site to inspect electrical connections front and rear.

2.06 BUS BARS AND INTERCONNECTIONS

A. Continuous Current Rating: 1200 amperes with sufficient cross-section to limit temperature rise at rated current to 55 degrees C.

B. Main Bus:

1. Totally enclosed by metal plates.
2. Silver-plated copper.

C. Ground Bus:

1. Material: Same as main bus.

2.07 CONTROL TRANSFORMER

A. Type: Insulated dry indoor.

B. Rating:

1. Output: 120-volt, single-phase, three-wire with two 2-1/2 percent taps above, and two 2-1/2 percent taps below, normal voltage.

2.08 TERMINAL BLOCKS

A. Rating: 600 volts, 30-ampere minimum.

B. Type:

1. One-piece barrier with strap screws.

2. Shorting type for current transformer leads.

3. Pull-apart control wiring terminal boards on drawout units.

2.09 CONTROL WIRING

A. NFPA 70, Type SIS, single-conductor, Class B, stranded copper, rated 600 volts for control, instrumentation, and power circuits.

B. Individual seven-strand, copper conductors, twisted and covered with a 100 percent aluminum, polyester shield with tinned copper drain wire and overall outer jacket, rated 600 volts, 90 degrees C minimum for transducer output and analog circuits.

C. Conductor Lugs: Pre-insulated, self-locking, spade type with reinforced sleeves.

D. Wire Markers: Each wire individually identified with permanent markers at each end.

E. Internal circuit wiring crossing shipping splits to have plug connectors.

F. Splices: Not permitted.

G. AC voltage sensing wiring shall be SIS #14 AWG. CT wiring shall be SIS #12 AWG. All DC control wiring shall be a minimum of #18 SIS AWG. Current transformer circuit termination's shall be ring tongue type and include options for shorting terminal blocks. Current transformer circuit terminations shall be ring tongue type and include shorting terminal blocks.

H. Control wires shall be numbered every eight (8) inches or less and visible next to the terminals. Also, the wiring shall be permanently marked with wire termination designations.

I. STATION BATTERY SYSTEM

1. Charger

The battery charger shall be rated for 25 Amps at 48 Volts output, with 120 single phase input voltage. The charger shall be provided with input and output circuit breakers. It shall be two rate type with a regulated output voltage stability of +/-1% from zero to full nominal rating over an input voltage variation of 10%. The charger shall include front-panel-mounted meter to display volts, amps and hours with float charge and high rate charge indicators. The charger shall also be equipped with failure alarm relay board to

provide alarm and status to the switchgear controls. The battery charger shall be SAFT AT10 or approved equal.

2. Battery

The storage batteries shall be pocket plate nickel cadmium designed for nominal 48VDC switchgear service and shall be sized per IEEE 485 and at a minimum capable of delivering 138 ampere hour capacity at the 5 hour rate. The battery cells shall SAFT SBM or approved equal.

3. Cabinet

The battery system including charger, batteries and spill containment shall be supplied in a freestanding rack (or cabinet). The rack (or cabinet) shall be seismic rated per 2006 IBC for the site specific location.

2.10 METERS AND INSTRUMENTS

A. As shown on drawings and match existing sections. Provide complete HMI and SCADA interface to read volts, amps, harmonics, provide waveform capture, etc. at remote SCADA system for each main, tie and branch and feeder circuit. Use Square D ION7650 as basis of design.

B. Switchgear manufacturer shall provide all necessary fiber optic media convertors, network switches, gateways, etc., to provide a seamless interface to the SCADA system.

C. Contractor will hold coordination meetings between the vendors of the switchgear, generators, SCADA system, VFD manufacturers, integrator, and all others deemed necessary to insure a fully coordinated SCADA and communication system and programming. Manufacturers shall provide the necessary engineers and personnel at such meetings to make the required component decisions and recommendations to the equipment design to insure full system communication coordination. Contractor shall hold a kickoff meeting between chosen vendors and sub-contractors to fully coordinate controls and integration.

D. Vendor shall be responsible to insure adequate CT ratios to maximize system protection and shall supply a CT model minimizing saturation issues.

E. Communications shall be by Ethernet TCP/IP. Provide managed switches, fiber converters, and appurtenances for a complete system interface to SCADA network.

2.11 EQUIPMENT IDENTIFICATION

A. Master Nameplate:

1. Deep etched aluminum with manufacturer's name and model number.

2. Riveted to main vertical section.

B. Section Identification:

1. Deep etched aluminum with manufacturer's name and model number.

2. Riveted to main vertical section.

C. Nameplate:

1. Engraved phenolic tags to match existing water plant tags.

D. WARNING SIGNS:

1. Provide warning signs such as danger, high voltage, keep out, etc.

2.12 FACTORY TESTING

A. Switchgear assembly production tested in accordance with ANSI C37.20.2.

B. Circuit breakers production tested in accordance with ANSI C37.09.

2.13 GENERATOR POWER AND CONTROL SECTION

A. Each generator section shall contain over-current protection, controls, relays and auxiliary devices associated with its respective engine generator set. It shall include the following:

For each generator set, a medium voltage vacuum circuit breaker shall be furnished to provide paralleling functions. Furnish circuit breakers with one vacuum interrupter per phase. Breakers of same type and rating shall be completely interchangeable. The circuit breaker shall be operated by means of a stored energy mechanism which is normally charged by a universal motor but can also be charged by the manual handle supplied on each breaker for manual emergency closing or testing. The closing speed of the moving contacts is to be independent of both the control voltage and the operator. Provide a full front shield on the breaker. A minimum of 6a & 6b auxiliary contacts, shall be provided for external use. Provisions shall be made for additional cell-mounted auxiliary contacts, both MOC and TOC type. The racking mechanism to move the breaker between positions shall be operable with the front door closed and position indication shall be visible with door closed.

An interlocking system shall be provided to prevent racking a closed circuit breaker to or from any position. An additional interlock shall automatically discharge the stored-energy operating mechanism springs upon removal of the breaker out of the compartment.

The circuit breaker control voltage shall be: *48* volts DC. Close and trip control power shall be independently monitored. Breaker closure shall be inhibited if trip power is unavailable.

A Circuit Breaker Trip Switch shall be provided with open/closed/tripped indicating LEDs.

B**.** Generator Control System

Paralleling controls for each generator shall include a programmable logic controller and a Woodward (or approved equal) DSLC-2 digital synchronizer and load controller designed for use on three-phase AC generators and mounted in the switchgear. The controls shall combine a synchronizer (with voltage matching capability), load sensor, load control, dead bus closing system interlock, VAR, power factor and process control. The load sharing network and VAR sharing network shall be completely integrated in the switchgear. Applications shall allow up to 32 generators to be paralleled and controlled.

The controls shall sense true RMS power and provide soft loading and unloading functions on the main bus.

DC-to-DC converter(s) shall be in each generator control section to provide a constant 24VDC power. The generator section DC-to-DC converter shall supplement the DC-to-DC converter in the master control section. Control power shall be sourced

from generator set batteries and sustain adequate control voltage during an engine crank. The converters shall provide power for up to 75% rated load if the source voltage drops to 12 volts. Source voltage shall not exceed 32 volts.

Refer to LG&E KU drawing SPEC-252-C Interconnection Requirements Figure 2 for protection scheme required to transfer loads back to utility with paralleling functions. Prior to submitting switchgear and MV transformers to engineer or owner contractor shall submit the transfer scheme and protection to Rodney Brock of LF&G KU for approval and provide written letter of acceptance.

Generator controls shall include the following functions, components, devices, and indicators.

1. Generator Voltage Monitoring and Frequency Monitoring

   Generator set controller shall monitor voltage and frequency to insure the generator is not connected to the bus until frequency is at least 59 Hertz and 90% rated voltage.

2. Automatic Synchronizer

   The synchronizer shall include a differential voltage detector, differential frequency detector and differential phase detector. Analog voltage bias signal shall be provided for voltage matching and an analog speed bias signal shall be provided for frequency matching and phase angle control. Synchronizer shall issue a breaker close signal when frequency, phase and voltage conditions are met.

   The differential voltage detector shall compare the voltage of the oncoming generator to the paralleling bus. If the voltage is not within the factory set difference of plus or minus 5% (adjustable from 0 to plus or minus 10%), the voltage detector shall inhibit the circuit breaker from closing. When the oncoming generator voltage is within the preset acceptable limit, the inhibit shall be removed.

   The differential frequency detector shall compare the frequency of the oncoming engine generator set to the paralleling bus. If the frequency is not within the preset acceptable difference of plus or minus 0.5 Hz (adjustable from 0 to plus or minus 0.5 Hz), the frequency detector shall inhibit the circuit breaker from closing. When the oncoming engine generator frequency is within the acceptable limit, the inhibit shall be removed.

   The differential phase detector shall compare the phase angle of the oncoming engine generator set to the paralleling bus. If the phase angle is not within the preset acceptable difference of plus or minus 0.05 Hz (adjustable from plus/minus 0.02 to 0.25 Hz), the phase detector shall inhibit the circuit breaker from closing. When the oncoming engine generator phase angle is within the acceptable limit, the inhibit shall be removed.

3. Multiple Circuit Interlock

   Generator controls shall provide for first-up, first-on operation of the generator set. This device shall positively prevent more than one set from being simultaneously connected to a dead bus. Upon initiation of the connection of the first set to the bus, this circuit shall shift the control of the remaining sets to automatic or manual synchronizing at the operator's discretion.

C. Engine Starting Control

1. The engine starting control logic shall be a programmable controller and shall automatically start, protect, and monitor each engine generator set. The controller shall be provided with power supply, CPU and required I/O modules. Generator start

control shall be hard wired so that the engine can be started if the controller is not available. The generator controller shall be dedicated for control exclusively of the engine and generator set and shall be independent of the Master PLC. Distributed I/O systems which rely on a master controller shall not be acceptable.

2. Engine Start/Stop Operation

   The automatic engine control logic shall initiate operation of the engine upon receipt of a signal from a contact that closes for engine run, and opens for engine stop.

3. Five Position Engine Control Selector Switch

   Lockout/Reset - When placed in this position, the engine shall not be capable of starting and/or running. If the engine was shut down due to the operation of a protective device, the shutdown shall be reset when the switch is moved to this position. If the engine is running when the switch is moved to this position, it shall immediately shut down.

   Off/Cooldown - When placed in this position, the engine shall shut down after soft unloading from the bus (provided another source is connected to the bus) and a cool-down period.

   Automatic - When placed in this position, the engine control shall be in readiness for fully automatic operation upon receipt of a start signal.

   Test Off-Line - When placed in this position, the engine shall start and run as if a start signal were received except it shall not be connected to the bus. If a start signal is received, normal automatic functions shall resume. When returned to the Automatic position, the engine shall shut down.

   Test On-Line - When placed in this position, the engine shall start, run, and connect to the bus. When returned to the Automatic position the circuit breaker shall open, provided no automatic start signal is present, and the engine shall run for its cool-down period before shutting down.

4. Four Position Synchronizing Mode Selector Switch

   Permissive - In this position the governor controls are deactivated. However, the synchronizer shall operate as a passive synch check relay and signal the closing of the generator breaker when both sources are in phase.

   Check - In this position the synchronizer is fully operational except it cannot close the generator breaker. The phase-lock feature holds the generator output in synchronism with the bus.

   Off - In this position the synchronizer is turned off to allow for manual paralleling at the Master Cubicle.

   Run - In this position the synchronizer is in the fully operational, automatic mode.

5. Engine Cooldown Time Delay

   The cooldown time delay shall be adjustable from 1 to 10 minutes (factory set at 5 minutes) and automatically bypassed for malfunction and manual shutdown of the engine generator set.

6. Failure to Synchronize Time Delay Relay

   The failure to synchronize time delay shall be fixed at 60 seconds. It shall provide

audible and visual indication, but it shall not terminate synchronizing attempts nor shut down the engine.

D. Circuit Breaker - Protective Relaying and Monitoring

A Generator management relay shall be provided to provide complete protection and monitoring functions.

Protection functions shall include:

- Instantaneous overcurrent when offline (50).
- High-set overcurrent (50).
- Instantaneous and definite time overcurrent for ground (50/51GN).
- Stator thermal modeling and RTD (49).
- Negative sequence overcurrent (46).
- Phase differential (87G) with a dedicated set of CT's.
- Over and undervoltage (59/27).
- Reverse power for anti-motoring (32).
- Voltage restrained phase overcurrent (51V).
- Voltage phase reversal (47).
- Loss of field (40 & 40Q).
- Over and under frequency (81).
- Synchronizing Check Device (25).
- AC Directional Overcurrent Relay (67).
- Neutral Voltage (59N)

Monitoring and metering functions shall include:

- RMS current, negative sequence current, voltage, three phase power, temperature (via the 12 RTDs).
- The protective relay shall include the following user interfaces:
    - 40 character LCD display, control keys and full numeric keypad located on the front panel.
    - LED indicators located on the front panel which shall indicate the status of the protection relay, generator, and output relays.
    - An RS232 port located on the front panel with a baud rate of 9600 bps.
    - Two RS485 ports located on the rear of the unit with baud rates from 300 to 19,200 bps.
    - Communications ports shall allow simultaneous independent access using Modbus® TCP/IP over Ethernet, Modbus RTU and DNP 3.0 protocol.
    - Windows® based PC software which enables setpoint programming, file storage, on-line help, and real time display of status and measured data.

The protective relay shall be provided with draw-out construction to facilitate testing, maintenance, and interchange flexibility. A separate Lockout Relay (Device 86) shall be provided for each protective relay. In conjunction with the generator differential (87G) protection above, which includes dedicated CT's in the switchgear as noted, another set of matching CT's shall be shipped loose with the switchgear to install on the generator for connection to the protective relay.

E. Alarm and Status Indication

FUNCTION	COLOR
LAMP TEST (PUSHBUTTON)	
PARALLEL CB OPEN	GREEN
PARALLEL CB CLOSED	RED
PARALLEL CB LOCKOUT	RED
PARALLEL CB FAIL TO CLOSE	RED
FAILURE TO SYNC	RED
GEN OUTPUT CB OPEN	GREEN
GEN OUTPUT CB CLOSED	RED
PARALLEL CB NOT CONNECTED	RED
PARALLEL CB FAIL TO OPEN	RED
OVER CRANK SHUTDOWN	RED
OVER SPEED SHUTDOWN	RED
REVERSE POWER SHUTDOWN	RED
LOW OIL PRESSURE SHUTDOWN	RED
HIGH WATER TEMP SHUTDOWN	RED
AUTO START	GREEN
ECS RESET REQUIRED	RED
ENGINE CONTROL NOT IN AUTO	RED
LOW OIL PRESSURE ALARM	AMBER
HIGH WATER TEMP ALARM	AMBER
ENGINE RUNNING	GREEN
PLC STOPPED	RED

FUNCTION	COLOR
CONTROL VOLTAGE FAILURE	RED
CONTROLS NOT IN AUTO	RED
LOCAL/REMOTE EMERGENCY STOP	RED
LOW WATER LEVEL ALARM	AMBER
LOW WATER TEMP ALARM	AMBER
POWERQUEST OVERRIDE	AMBER
DAY TANK LOW FUEL	AMBER
DAY TANK HIGH FUEL	AMBER
DAY TANK RUPTURE BASIN	AMBER
BATTERY CHARGR FAILURE	RED
HIGH BATTERY VOLTAGE	AMBER
LOW BATTERY VOLTAGE	AMBER
(Protective Relay) COMMON ALARM	AMBER
(Protective Relay) COMMON SHUTDOWN	RED
125VDC TRIP/CLOSE VOLTAGE FAILURE	RED
GEN COMMON SHUTDOWN	RED
GEN COMMON ALARM	AMBER
DC CONVERTER FAILURE	RED
DSLC-2 SELF TEST FAILED	RED
LOW OIL TEMPERATURE	RED

F. Generator Metering / Instrumentation.

1. Ammeter.
2. Voltmeter.
3. Kilowatt meter.
4. Frequency meter.
5. 4 Position Ammeter/Voltmeter selector switch means shall be included.

G. Generator Control Station

FUNCTION	SELECTIONS
GENERATOR CONTROL SWITCH	LOCKOUT/RESET OFF/COOLDOWN AUTOMATIC TEST OFFLINE TEST ONLINE
SYNCHRONIZING MODE SWITCH	PERMISSIVE CHECK OFF/COOLDOWN RUN
EMERGENCY STOP PUSHBUTTON	-
ALARM RESET PUSHBUTTON	-
VOLTAGE CONTROL SWITCH	LOWER OFF RAISE
SPEED CONTROL	LOWER OFF RAISE

2.14 MASTER CONTROL SECTION

A. Priority Load Control

Discrete output modules shall be provided to control the necessary priority load blocks. The number of load blocks shall equal the number of engine generator sets, and shall be sized such that the connectable load of each block is not greater than the kilowatt rating of the generator set connected. As the generators are connected to the bus, the controller shall signal for the connection of the load blocks in an ascending sequential priority with the highest priority load requiring emergency power being connected first. Priority failure pass-along logic shall initiate the connection of low priority loads to the first generator on-line if start signals have not been received from high priority transfer switches or other devices.

Load shedding shall be done on a last-on, first-off basis. The generator bus shall have a solid-state frequency monitor, with integral time delay to initiate load shedding upon a reduction of bus frequency to 58 Hz or less, for a period of three seconds or more. Upon sensing a bus underfrequency, the system shall automatically shed the lowest priority load connected at the time of occurrence. This shed circuit shall override any manual load-add operation, and shall lock out the manual load-add circuitry. It shall provide visual and audible alarm annunciation of bus underfrequency load shed.

Provide a means to reset bus underfrequency signal.

Provide a “load shed bypass/reset” push-button, for manual supervised operation over the load-shed, load-add control logic. One push-button shall be provided for each priority block except first priority. Logic shall be provided in the event that a bus overload occurs resulting in a reduction in bus frequency; the bypassed priority load shall be shed automatically through override logic control.

B. Power Management Applications

Master controls applications shall include Load Bus Optimization and Generator Load Demand. Applications shall dynamically adjust to accommodate a segmented main bus or a single main bus as tie breakers open or close.

Generator Load Demand shall control up to 32 individually prioritized and separately controlled engine-generator sets. Engine-generator sets shall be added or removed from a bus segment according to dynamic measurements of power consumption and engine-generator efficiency set-points.

C. Manual Paralleling Controls

A Synchroscope selector switch shall be provided to select any generator for manual paralleling operation. The positioning of the selector switch shall simultaneously connect the synch-check relay, Synchroscope, and “manual paralleling” push-button to the selected generator.

Two voltmeters and two frequency meters shall respectively indicate oncoming source and the main bus.

A solid-state sync check relay shall be furnished for manual paralleling, to sense and compare the phase angle difference between the oncoming generator and the bus. This relay shall lockout the manual paralleling push-button until the oncoming generator is within 15 degrees of synchronism.

Operation shall be arranged so the operator shall depress and hold the manual paralleling push-button. When the relative phase angle reduces to 15 degrees and going towards zero degrees, the sync check relay’s output contact shall initiate the closing of the respective oncoming generator breaker.

All manual paralleling interface controls and metering shall be grouped in a central location on the front of the master control section. This shall allow for multiple generators paralleling from one location within the switchgear. Manual paralleling controls and sync check relay shall be hardwired and shall not rely on touch screens or programmable controllers to perform manual paralleling functions.

D. DC Control Power Selector – Best Battery System

Control power for the system logic shall be derived from the engine starting batteries and/or an optional station battery system. The control logic shall be powered through a suitable means that shall permit continuity of power until the last battery is no longer available. The controls shall be powered from any battery or combination of batteries and prevent feedback to a failing battery. The transition of control logic power from any battery combination to any other battery combination shall be accomplished without disruption in the power flow.

A single DC-to-DC converter shall provide a constant 24VDC power to the master and generator controllers during starting and cranking of all engine generator sets “simultaneously”.

Additionally, the best battery system shall provide power to each generator paralleling

circuit breaker trip coil if the generator battery power is lost to its cubicle.

Station batteries shall be converted to 24VDC to provide backup to DC controls.

E. System Test Switch

Provide a system no-load test switch to initiate a complete automatic system operation by simulating the closure of the remote engine start signal. This switch shall be mounted inside the master section to limit access to authorized personnel only.

F. Alarm and Status Indication

FUNCTION	COLOR
LAMP TEST (PUSHBUTTON)	
GEN # RUNNING	GREEN
GEN # ONLINE	RED
GEN # LOCKED OUT	RED
PRI # LOAD SHED ACTIVE	AMBER
PRI # LOAD SHED BYPASSED	AMBER
SYSTEM TEST	AMBER
EMERGENCY MODE	AMBER
I/O COMM FAILURE	RED
SYSTEM PLC DIAGNOSTIC FAULT	AMBER
LOAD DEMAND MODE ACTIVE	AMBER
LOAD DEMAND START TD ACTIVE	AMBER

FUNCTION	COLOR
LOAD DEMAND STOP TD ACTIVE	AMBER
BUS UNDER FREQUENCY	RED
BUS OVER FREQUENCY	RED
BUS UNDER VOLTAGE	RED
BUS OVER VOLTAGE	RED
BUS OPTIMIZATION MODE ACTIVE	AMBER
NEXT LOAD EXCEEDS HEADROOM	AMBER
BUS LOADED TO CAPACITY	AMBER
BUS OVERLOAD	RED
STATION BATTERY CHARGER FAILURE	AMBER
MAIN TANK LOW FUEL	AMBER
ATS CONTROL FUSE BLOWN	RED
PLC 1 STOPPED	RED
PLC 2 STOPPED*	RED
CONTROL VOLTAGE FAILURE	RED
DC CONVERTER FAILURE	RED

** for redundant option*

G. Main Audible Alarm

Provide a main audible alarm. The alarm horn shall be the DC vibration type, subsequent malfunctions to resound the alarm if the horn had been previously silenced.

H. Paralleling Bus Metering / Instrumentation

1. Ammeter
2. Voltmeter
3. Kilowatt Meter
4. Frequency Meter
5. Synchroscope
6. 4 Position Ammeter/Voltmeter selector switches for bus metering shall be included.

I. Main Bus Monitoring

Main bus monitoring for each generator bus segment shall include a discrete Bus Under/Overvoltage Relay, a discrete Bus Under/Over-Frequency Relay and a Main Bus Power Watt Transducer.

J. Master Control Station

FUNCTION	COLOR
BUS ALARM RESET PUSHBUTTON	-
ALARM SILENCE PUSHBUTTON	RED
MANUAL PARALLEL PUSHBUTTON	GREEN
PRIORITY # LOAD SHED PUSHBUTTON	-

K. Master Controller

The master controller shall be programmed by ASCO and shall meet or exceed the following specifications:

1. GE RX3i with CPU, power supply, I/O, and communications.

2. The controller shall have the capability to interface to a remote I/O rack.

2.15 DISTRIBUTION SECTIONS

Provide circuit breaker control switches for all circuit breakers. Control switches shall have built in indicating lights to indicate breaker status (open, closed, tripped). Manually opening the circuit breaker with the breaker control switch shall inhibit automatic operation and shall be annunciated on the one-line screen.

A. One High Feeder Breaker Sections shall be provided as shown the project drawings and shall contain the following components:

1 Vacuum circuit breaker with Auxiliary Contacts, MOC and TOC Switches (charge, close and trip voltage
3 Current transformers for metering and relays, ratio as shown on drawings
1 Circuit Breaker Control Switch with open/closed/tripped LEDs
1 Feeder Protective Relay with overcurrent protection provided in draw-out case
1 Device 86, lockout relay

B. One High Feeder Breaker & Main Bus PT Section

1 Vacuum circuit breaker with Auxiliary Contacts, MOC and TOC Switches (charge, close and trip voltage
3 Current transformers for metering and relays, ratio as shown on drawings
1 Circuit Breaker Control Switch with open/closed/tripped LEDs
1 Feeder Protective Relay with overcurrent protection provided in draw-out case
1 Device 86, lockout relay
2 Main Bus Potential Transformers, ratio as required

C. Two High Feeder Breaker Sections shall be provided as shown the project drawings and shall contain the following components:

2 Vacuum circuit breakers, each with Auxiliary Contacts, MOC and TOC Switches (charge, close and trip VOLTAGE
6 Current transformers for metering and relays, ratio as shown on drawings
2 Circuit Breaker Control Switches with open/closed/tripped LEDs
2 Feeder Protective Relays with overcurrent protection provided in draw-out case
2 Device 86, lockout relays

2.17 SEQUENCE OF OPERATION

A. Single Utility Loss Operating Mode

There are two utility lines feeding the site referred to as PREFERRED and SECONDARY. THE SECONDARY cannot carry the existing plant and new plant loads. When the PREFERRED utility is lost and the SECONDARY is available the system will immediately open both utility main breakers. After a short time delay (adjustable from 1-14 seconds), if PREFERRED power is not restored, the system shall start generators and run on generator power until PREFERRED power is restored OR until a manual command via SCADA or the local OIT from the plant operators switches the system back to SECONDARY utility.

When the failed PREFERRED utility returns, a time delay (user adjustable) will be started. When this time delay expires and the system is in closed transition mode it will close the returned utility breaker and then open the generator main breakers. This shall be supervised by a synch check relay. If the two sources are not in parallel within one minute, an alarm will sound and return to failed utility will be aborted.

If either Utility Breaker is “LOCKED OUT” by the protective relay, a lamp will light in the Master Control & Remote Annunciator panel. This will require the operator to investigate the system.

B. Generator Operating Mode

Whenever the individual engine generator control switches are placed in their automatic position, the engine generator system is on standby in readiness for automatic starting and synchronization in the event of a power failure signal. In the event of a total power failure & the engine generator sets automatically start and come up to speed. When any single generator is running either automatically or locally, a signal from the switchgear shall be send to open the building louvers. When the first generator achieves 90% of rated voltage and frequency its respective circuit breaker is closed and the generator is connected to the emergency bus. Electronic interlocks permit the connection of only one generator in the event of simultaneous generator relay operation. All remaining generators' synchronizers will automatically adjust their speed (frequency) to produce synchronism with the bus. When synchronism is achieved, the on-coming generators are paralleled to the bus. Once (adjustable) two generators are online, the system will add the primary side loads.

If one generator fails while operating in Emergency Mode, it is disconnected from the bus and shutdown.

If at any time the bus frequency drops to 58 Hz or less for more than 2 seconds, the lowest priority loads are shed by opening breaker**.** A status light annunciating “Bus Underfrequency” shall be activated and the alarm horn sounded. The bus underfrequency control is maintained until examined by the plant operator. After taking appropriate action the condition may be reset via the “Bus Alarm Reset” Pushbutton.

C. Return from Loss of Utility

When the PREFERRED utility source returns a timer (adjustable from 1-30 minutes) will be started. When that timer expires the system will determine if both utilities are available or only one is available to determine if it will return to a single utility or return to split utility.

D. Closed Transition

In the transition mode switch is in closed the system will parallel the system to the PREFERRED utility and close the utility breaker. If the power system has been placed on the SECONDARY utility manually, a manual command from SCADA or the OIT shall initiate closed transition back to the utility service.

E. Malfunction Operation

Upon initiation of a malfunction, the generator set will be removed from the bus and shutdown. The lowest priority loads will be shed to the disabled normal. Shutdown and lockout are provided for:

Engine high water temperature
Engine low oil pressure
Engine overspeed
Engine overcrank
Generator reverse power
Generator overcurrent
Control Voltage Failure
Parallel Circuit Breaker Close Failure
PLC Stopped

The following common shutdown alarms are displayed on the SR489 protective relay screen and annunciates “generator common shutdown”.

- Engine loss of excitation
- Negative sequence overcurrent
- Overcurrent with voltage restraint
- Generator Differential

Audible and visual alarm signals are activated for any of the above malfunctions.

Audible and visual alarms will be activated upon sensing a bus underfrequency. This malfunction as well as any shutdown malfunctions, will require manual resetting.

An audible alarm silence circuit is provided. The audible alarm silence is reset upon reset of the malfunction or upon the occurrence of a malfunction after the alarm has been silenced. The audible alarm will annunciate each malfunction and pre-alarm.

F. Test Facilities

1. No Load Test

No Load Testing of the system is accomplished by turning the system control switch to Test from the switch located behind the Master section door. This will allow all the Generators to start and connect to the HV Generator Bus.

To go back to automatic turn the Test switch to Auto from the switch located on the front of the Master section. All of the engine generator breakers will open and the engine generators will go into their cooldown sequence. After the cooldown period of approximately 5 minutes, the engine generators will shut down.

If there is a loss of Normal Power while operating in the Test Mode, the Test Mode is suspended. The system will follow normal Emergency Mode operations as described above.

If the system is feeding both load groups from one utility no load test will be inhibited.

2. Partial Load Test

When the system is fully operational prior to owner acceptance, perform a partial load test. Initiate a simulated loss of each utility service while under load. Generators will start up, close to a dead bus as described under normal operation, take on load, run for 5 minutes, and parallel back to the restored utility source. Set return time temporarily to 5 minutes during test and back to 15 minutes after test.

G. Load Demand

Load Demand Operation controls the number of generators running and connected to the emergency bus based on the actual load demand of the facility. This mode of operation monitors the emergency bus kW and determines the number of generators required to support the load without overloading the generators. The Load Demand Mode can be disabled via the “Load Demand Mode” on-off toggle switch located inside the Master Control Section.

If load demand is enabled and the system is operating in the emergency or test mode, a stabilization time delay is initiated after all generator sets have been paralleled to the bus and all loads connected. At the expiration of the time delay period the system will determine the required number of generators to support the actual load. The system will remove any automatic start signals to the lowest priority generator that is not required, removing it from the emergency bus and allowing it to go through its cooldown cycle. At no time will the system allow less than one engine generator to be connected to the emergency bus.

Upon sensing that the load has increased to 70% or more (adjustable) of the on-line capacity of 1 generator, a time delay is initiated. If the load remains above the 70% level for the duration of the time delay, the controls will initiate the starting and paralleling of the next Generator set in Priority sequence. If during the delay period the load exceed 90 pct the time delay will be terminated and the next generator will be given an immediate start.

If, during the time delay period, the load level increases to 110% of the on-line Generator capacity, the time delay will be bypassed. The second set will be immediately started and paralleled. Concurrent to the 110% immediate start of the next Generator, the lowest block of load will be shed to prevent over loading of any of the on line Generator(s). When the next Generator is paralleled to the Bus, the shed load will be automatically reconnected to the Bus. However, with the 70% time delayed start, no load shedding will occur.

Should the next Generator set fail to synchronize within the preset time period of the Fail-To-Synchronize time delay, the controls will send a signal to the SCADA to allow it to remove loads as determined in a preconfigured load profile or manually by the operator from the control terminal. If both generators are running and required for the load and one fails, an alarm shall be sent to SCADA to allow it to remove loads as determined in a preconfigured load profile or manually by the operator from the control terminal.

If, while operating in the Load Demand mode, an Engine Generator set malfunction occurs, the affected Generator set will be removed from the Bus. Load Demand Operation is reset and all available Generators will be started and all loads will be reconnected except as determined by the SCADA system or operator manually. These loads may be added manually by an operator if it is determined that it will not overload the system as described earlier. The stabilization time delay will be reset after all available Generator(s) have been connected to the Bus. Once it expires, the Load Demand operation is resumed.

H. Load Shed Operation

Provide dry contact to the site SCADA when load shed is required to avoid generator damage..

I. Manual Operation

Manual operation of the system is possible via control switches.

Generators may be manually started by placing their Engine Control switches in the RUN position. This will bring the selected generators onto the generator bus if they will not parallel with the utility.

Manual operation of Utility Main and Generator Main breakers is also available via their control switches. This will be by selectable Closed or Open transition operation. In Closed transition the system shall be interlocked to prevent closing breakers inappropriately and synchronizing with the utility shall be handled by the controller and synch relay. Either of those breaker may be tripped at any time but close will only be permitted when both breakers are open.

If the system is returned to AUTO the PLC will look at the current position of breakers and switches and determine if it needs to start sequences. All timers will be starting from that point, so if one of the loads is on generators and the utility is available, it will start timing for a return to utility.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install equipment in accordance with manufacturer's instructions and recommendations.

B. Secure equipment to floor with anchor bolts of sufficient size and number adequate for specified seismic conditions.

C. Install equipment plumb and in longitudinal alignment with wall.

D. Tighten current-carrying bolted bus connections and enclosure framing and panel bolts to manufacturer's recommendations.

E. Coordinate terminal connections with installation of secondary feeders.

3.02 FIELD QUALITY CONTROL

A. In accordance with Section 16050, BASIC ELECTRICAL MATERIAL AND METHODS.

3.03 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at site for minimum person-days listed below, travel time excluded:

1. 2 person-days for installation assistance

2. 1 person-days for pre-startup classroom or site operational training.

3. 1 person-days for facility startup.

B. Testing: In accordance with Section 16050 and the following:

1. Make insulation resistance tests of switchgear buses, components, and connecting supply, feeder, and control circuits.

2. Make continuity test of circuits.

3. Perform test procedures required by the manufacturer's installation and testing instructions.

4. Perform mechanical and electrical operator tests. Check main and auxiliary contact alignment.

5. Check arc interrupter operation on load interrupter switches.

6. Verify key interlock operation.

7. Test insulation resistance on each phase to ground and from each phase to each other phase.

8. Test AC over-potential in accordance with applicable ANSI/IEEE standards.

9. Test contact resistance across each main contact set. Report contact resistance in excess of manufacturer's tolerances.

10. Test protective relays to determine pickup parameters. Verify accuracy of timing setting for 3 points on time dial curve.

11. Trip each circuit breaker by operating each associated protective relay.

12. Measure minimum pickup voltage of each trip and close coil.

13. Test arc chutes for losses in accordance with manufacturer's instructions.

14. Verify operation of auxiliary and emergency equipment.

C. Retesting: Correct deficiencies identified by tests and completely retest switchgear. Verify by the system test that the total system meets the specified requirements.

END OF SECTION

SECTION 16436 - LOW-VOLTAGE SWITCHGEAR

PART 1 – GENERAL

1.01 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

1. AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

    a. ASHRAE 90.1 - IP (2010; ERTA 2011-2013) Energy Standard for Buildings Except Low-Rise Residential Buildings

2. ASTM INTERNATIONAL (ASTM)

    a. ASTM A123/A123M (2013) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

    b. ASTM A153/A153M (2009) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

    c. ASTM A240/A240M (2015) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

    d. ASTM A653/A653M (2013) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

    e. ASTM A780/A780M (2009) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

    f. ASTM D149 (2009; R 2013) Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

    g. ASTM D1535 (2014) Specifying Color by the Munsell System

    h. ASTM D709 (2013) Laminated Thermosetting Materials

3. INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

    a. IEEE 100 (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms

    b. IEEE 81 (2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

    c. IEEE C2 (2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code

    d. IEEE C37.13 (2008; INT 1 2009; AMD 1 2012) Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

e. IEEE C37.20.1 (2002; INT 1 2005; AMD A 2005; AMD B 2006; R 2007) Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear

f. IEEE C37.20.7 (2007; ERTA 2008; INT 1 2009; CORR 1 2010) Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults

g. IEEE C37.90.1 (2012) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus

h. IEEE C57.12.28(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity

i. IEEE C57.12.29(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments

j. IEEE C57.13 (2008; INT 2009) Standard Requirements for Instrument Transformers

4. INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

a. NETA ATS (2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

5. NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

a. ANSI C12.1 (2008) Electric Meters Code for Electricity Metering

b. NEMA ICS 6 (1993; R 2011) Enclosures

c. NEMA LI 1 (1998; R 2011) Industrial Laminating Thermosetting Products

d. NEMA ST 20 (1992; R 1997) Standard for Dry-Type Transformers for General Applications

6. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

a. NFPA 70 (2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

7. UNDERWRITERS LABORATORIES (UL)

a. UL 1558 (1999; Reprint Apr 2010) Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

b. UL 467 (2007) Grounding and Bonding Equipment

1.02 SCOPE OF WORK

A. This specification covers the requirements for low voltage switchgear.

1.03 DEFINITIONS

A. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE 100.

1.04 SUBMITTALS

A. Shop Drawings:

1. Descriptive product information.
2. Dimensional drawings.
3. Itemized bill of material.
4. Protective device time-current characteristics on transparencies.
5. Operational description.
6. Installation instructions.
7. Bus data.
8. One-line, three-line, and control schematic drawings.
9. Connection and interconnection drawings.
10. Conduit entrance locations.
11. Communication drawings for internal and external devices.

1.05 MANUFACTURERS

A. ABB.

B. Square D.

C. General Electric.

PART 2 – PRODUCTS

2.01 GENERAL

B. Include manufacturer's information on each submittal for each component, device and accessory provided with the switchgear including:

1. Circuit breaker type, interrupting rating, and trip devices, including available settings.
2. Manufacturer's instruction manuals and published time-current curves (in electronic format) of the main secondary breaker and largest secondary feeder device.
3. Communication layout, devices and wiring.

4. Power quality monitors

2.02 SWITCHGEAR DRAWINGS

A. Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Identify circuit terminals on wiring diagrams and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Indicate on the drawings adequate clearance for operation, maintenance, and replacement of operating equipment devices. Include the nameplate data, size, and capacity on submittal. Also include applicable federal, industry, and technical society publication references on submittals. Include the following:

1. One-line diagram including breakers, fuses, current transformers, and meters.

2. Outline drawings including front elevation, section views, footprint, and overall dimensions.

3. Bus configuration including dimensions and ampere ratings of bus bars.

4. Markings and NEMA nameplate data, including fuse information (manufacturer's name, catalog number, and ratings).

5. Circuit breaker type, interrupting rating, and trip devices, including available settings.

6. Wiring diagrams and elementary diagrams with terminals identified, and indicating prewired interconnections between items of equipment and the interconnection between the items.

7. Manufacturer's instruction manuals and published time-current curves (in electronic format) of the main secondary breaker and largest secondary feeder device. Use this information (designer of record) to provide breaker settings that ensures protection and coordination are achieved. Provide electronic format curves using SKM's Power Tools for Windows device library electronic format or EasyPower device library format depending on installation modeling software requirements.

2.03 STANDARD PRODUCTS

A. Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship, and:

1. Have been in satisfactory commercial or industrial use for 2 years prior to bid opening including applications of equipment and materials under similar circumstances and of similar size.

2. Have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

3. Where two or more items of the same class of equipment are required, provide products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

2.04 ALTERNATIVE QUALIFICATIONS

A. Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

2.05 MATERIAL AND EQUIPMENT MANUFACTURING DATE

A. Products manufactured more than 1 year prior to date of delivery to site are not acceptable.

2.06 MAINTENANCE

A. Switchgear Operation and Maintenance Data: Submit Operation and Maintenance Manuals in accordance with Submittal sections.

B. Assembled Operation and Maintenance Manuals: Assemble and securely bind manuals in durable, hard covered, water resistant binders. Assemble and index the manuals in the following order with a table of contents:

1. Manufacturer's O&M information.
2. Catalog data.
3. Drawings.
4. Prices for spare parts and supply list.
5. Information on metering.
6. Design test reports.
7. Production test reports.

2.07 WARRANTY

A. Provide equipment items that are supported by service organizations reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

2.08 PRODUCT COORDINATION

A. Products and materials not considered to be switchgear and related accessories are specified in Section 16442, Panelboards, and Section 16440, Motor Control.

2.09 SWITCHGEAR

A. IEEE C37.20.1 and UL 1558.

1. Ratings - Provide equipment with the following ratings:
    a. Voltage rating: 480Y/277 volts AC, as indicated.
    b. Continuous current rating of the main bus: as indicated on plans.
    c. Short-circuit current rating: 100,000 rms symmetrical amperes.
    d. UL listed and labeled for its intended use.

B. Construction - Provide the following:

1. Switchgear: consisting of vertical sections bolted together to form a rigid assembly.

2. All circuit breakers: front accessible with rear load connections.

3. Compartmentalized switchgear: vertical insulating barriers between the front device section, the main bus section, and the cable compartment.

4. Where indicated, "space for future" or "space" means to include all necessary components and hardware to be fully equipped for racking in a circuit breaker element.

5. Insulating barriers: provided in accordance with NEMA LI 1, Type GPO-36.35 mm (0.25 inch) minimum thickness.

6. Moisture resistant coating: applied to all rough-cut edges of barriers.

7. Switchgear: Arc-resistant Type 1B, tested in accordance with IEEE C37.20.7.

C. Enclosure - Provide the following:

1. Enclosure: NEMA ICS 6 Type 1.

2. Enclosure: bolted together with removable bolt-on side and hinged rear covers.

3. Front and rear doors: provided with padlockable vault handles with a three point catch.

4. Galvanized steel: ASTM A123/A123M, ASTM A653/A653M G90 coating, and ASTM A153/A153M, as applicable. Galvanize after fabrication where practicable.

5. Paint color: ASTM D1535 light gray No. 61 or No. 49 over rust inhibitor.

6. Paint coating system: comply with IEEE C57.12.28 for galvanized steel.

7. Infrared viewing windows: install to allow the use of an infrared camera or thermal imager direct line of site to inspect electrical connections without requiring the opening of panels and doors. These windows are intended to allow thermographers the ability to inspect the electrical equipment without directly exposing themselves to live electrical components and energized devices.

D. Bus Bars - Provide the following:

1. Bus bars: copper with silver-plated contact surfaces.

   a. Phase bus bars: uninsulated.

   b. Neutral bus: rated 25 percent of the main bus continuous current rating as indicated.

2. Make bus connections and joints with hardened steel bolts.

3. Main-bus (through bus): rated at the full ampacity of the main throughout the switchgear.

4. Minimum 6.35 mm by 50.8 mm (one-quarter by 2 inch) copper ground bus secured to each vertical section along the entire length of the switchgear.

E. Main Section - Provide the main section consisting of an individually mounted, drawout, air power circuit breaker. Provide each main with a Square-D 7650 power quality monitor with Ethernet connectivity to SCADA.

F. Distribution Sections - Provide the distribution sections consisting of individually mounted, drawout, air power circuit breakers as indicated. Provide each with a Square-D series 5000 meter and Ethernet connectivity to SCADA.

G. Auxiliary Sections - Provide auxiliary sections consisting of indicated instruments, metering equipment, control equipment, and current transformer compartments.

H. Handles - Provide handles for individually mounted devices of the same design and method of external operation. Label handles prominently to indicate device ampere rating, color coded for device type. Identify ON-OFF indication by handle position and by prominent marking.

I. Protective Device - Provide main and branch protective devices as indicated. Provide the following:

1. IEEE C37.13. manually operated drawout, unfused, low-voltage power circuit breaker with a short-circuit current rating of 100,000 rms amperes symmetrical at 480 volts.

2. Breaker frame size: as indicated.

2.10 DRAWOUT BREAKERS

A. Equip drawout breakers with disconnecting contacts, wheels, and interlocks for drawout application. Provide main, auxiliary, and control disconnecting contacts with silver-plated, multifinger, positive pressure, self-aligning type. Provide drawout compartment shutters to protect operators from accidental contact with breaker stabs when the breaker is withdrawn from its cubicle. Provide each drawout breaker with four-position operation with each position clearly identified by an indicator on the circuit breaker front panel as follows.

1. Connected Position: Primary and secondary contacts are fully engaged. Breaker must be tripped before racking into or out of position.

2. Test Position: Primary contacts are disconnected but secondary contacts remain fully engaged. This position allows complete test and operation of the breaker without energizing the primary circuit.

3. Disconnected Position: Primary and secondary contacts are disconnected.

4. Withdrawn (Removed) Position: Places breaker completely out of compartment, ready for removal. Removal of the breaker actuates assembly that isolates the primary stabs.

5. Provide remote monitoring of breaker status to SCADA as: RACKED ON TRIPPED UNRACKED OFF.

2.11 ELECTRONIC TRIP UNITS

A. Equip breakers with a solid-state tripping system consisting of three current sensors and a microprocessor-based trip unit that provides true rms sensing adjustable time-current circuit protection. Include the following:

1. Current sensors ampere rating: the same as the breaker frame rating.

2. Trip unit ampere rating: as indicated.

3. Ground fault protection: as indicated.

4. Electronic trip units: provide additional features:

   a. Breakers: include long delay pick-up and time settings, and indication of cause of circuit breaker trip.

   b. Main breakers: include short delay pick-up and time settings and instantaneous settings and ground fault settings.

   c. Distribution breakers: include short delay pick-up and time settings, instantaneous settings.

   d. Breakers: include a digital display for phase and ground current. Provide amps and volts via Ethernet TCP/IP to SCADA.

   e. Main Breakers: include a digital display for phase voltage, and percent THD voltage and current.

   f. Breakers: include provisions for communication via a network twisted pair cable for remote monitoring and control. Provide the following communications protocol: Ethernet TCP/IP to SCADA.

2.12 METERING

A. Digital Meters

1. IEEE C37.90.1 for surge withstand. Provide true rms, plus/minus one percent accuracy, programmable, microprocessor-based meter enclosed in a sealed case with the following features.

   a. Display capability:

      (1) Multi-Function Meter: Display a selected phase to neutral voltage, phase to phase voltage, percent phase to neutral voltage THD, percent phase to phase voltage THD; a selected phase current, neutral current, percent phase current THD, percent neutral current; selected total PF, kW, KVA, kVAR, FREQ, kVAh, kWh. Detected alarm conditions include over/under current, over/under voltage, over/under KVA, over/under frequency, over/under selected PF/kVAR, voltage phase reversal, voltage imbalance, reverse power, over percent THD. Include a Form C KYZ pulse output relay on the meter.

      (2) Ammeter: Display phase A, B, and C currents. Detected alarm conditions include over/under current, over percent THD.

   b. Provide programming via a front panel display and a communication interface accessible by a computer.

   c. Provide password secured programming stored in non-volatile EEPROM memory.

   d. Provide digital communications in a Modbus TCP/IP protocol.

e. Provide meter with a display of Total Harmonic Distortion (THD) measurement to a minimum of the thirty-first order.

f. Include historical trend logging capability with the ability to store up to 100,000 data points with intervals of 1 second to 180 minutes. Provide a unit that can store and time stamp up to 1000 programmable triggered conditions.

g. Provide event waveform recording triggered by the rms of 2 cycles of voltage or current exceeding programmable set points. Store waveforms for all 6 channels of voltage and current for a minimum of 10 cycles prior to the event and 50 cycles past the event.

B. Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Provide short-circuiting type terminal boards associated with current transformer. Terminate conductors for current transformers with ring-tongue lugs. Provide terminal board identification that is identical in similar units. Provide color coded external wiring that is color coded consistently for similar terminal boards.

C. Wire Marking

Mark control and metering conductors at each end. Provide factory installed, white, plastic tubing, heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide white, preprinted, polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Provide a single letter or number on each sleeve, elliptically shaped to securely grip the wire, and keyed in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Indicate on each wire marker the device or equipment, including specific terminal number to which the remote end of the wire is attached.

D. Manufacturer’s Nameplate

Provide a nameplate on each item of equipment bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable. This nameplate and method of attachment may be the manufacturer's standard if it contains the required information.

E. Field Fabricated Nameplates

ASTM D709. Provide laminated plastic nameplates for each switchgear, equipment enclosure, relay, switch, and device; as specified in this section or as indicated on the drawings. Identify on each nameplate inscription the function and, when applicable, the position. Provide nameplates of melamine plastic, 3 mm (0.125 inch) thick, white with black center core. Provide matte finish surface. Provide square corners. Accurately align lettering and engrave into the core. Provide nameplates with minimum size of 25 by 65 mm (one by 2.5 inches). Provide lettering that is a minimum of 6.35 mm (0.25 inch) high normal block style.

2.13 COORDINATED POWER SYSTEM PROTECTION

A. Provide a power system study as specified in Section 16015, Electrical System Analysis.

2.14 ARC FLASH WARNING LABEL

A. Provide a power system study as specified in Section 16015, Electrical System Analysis. Provide warning label for switchgear. Locate this self-adhesive warning label on the

outside of the enclosure warning of potential electrical arc flash hazards and appropriate PPE required. Provide label format as indicated.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Conform to IEEE C2, NFP 70, and to the requirements specified herein. Provide new equipment and materials unless indicated or specified otherwise.

3.02 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

A. Install and connect equipment furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

1. Switchgear: IEEE C37.20.1.

2. Meters and Instrument Transformers: ANSI C12.1.

3. Field Applied Painting: Where field painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance with manufacturer's instructions.

4. Galvanizing Repair: Repair damage to galvanized coatings using ASTM A780/A780M, zinc rich paint, for galvanizing damaged by handling, transporting, cutting, welding, or bolting. Do not heat surfaces that repair paint has been applied to.

5. Field Fabricated Nameplate Mounting: Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.03 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

A. Interior Location - mount switchgear on concrete slab as follows:

1. Unless otherwise indicated, provide the slab with dimensions at least 100 mm (4 inches) thick.

2. Install slab such that the top of the concrete slab is approximately 100 mm (4 inches) above the finished grade.

3. Provide edges above grade with 15 mm (1/2 inch) chamfer.

4. Provide slab of adequate size to project at least 200 mm (8 inches) beyond the equipment.

5. Provide conduit turnups and cable entrance space required by the equipment to be mounted.

6. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant.

7. Cut off and bush conduits 75 mm (3 inches) above slab surface.

3.04 FIELD QUALITY CONTROL

A. Submit Required Settings of breakers to the Contracting Officer after approval of switchgear and at least 30 days in advance of their requirement.

B. Performance of Acceptance Checks and Tests: Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

C. Switchgear

1. Visual and Mechanical Inspection

a. Compare equipment nameplate data with specifications and approved shop drawings.

b. Inspect physical, electrical, and mechanical condition.

c. Verify appropriate anchorage, required area clearances, and correct alignment.

d. Clean switchgear and verify shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.

e. Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.

f. Verify that fuse and circuit breaker sizes and types correspond to approved shop drawings as well as to the circuit breaker’s address for microprocessor-communication packages.

g. Verify that current transformer ratios correspond to approved shop drawings.

h. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

i. Confirm correct operation and sequencing of electrical and mechanical interlock systems.

j. Confirm correct application of manufacturer's recommended lubricants.

k. Inspect insulators for evidence of physical damage or contaminated surfaces.

l. Verify correct barrier and shutter installation.

m. Exercise all active components.

n. Inspect all mechanical indicating devices for correct operation.

o. Verify that filters are in place and vents are clear.

p. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects.

q. Inspect control power transformers.

2. Electrical Tests

a. Perform insulation-resistance tests on each bus section.

b. Perform dielectric withstand voltage tests.

c. Perform insulation-resistance test on control wiring. Do not perform this test on wiring connected to solid-state components.

d. Perform control wiring performance test.

e. Perform primary current injection tests on the entire current circuit in each section of assembly.

D. Circuit Breakers - Low Voltage - Power

1. Visual and Mechanical Inspection

a. Compare nameplate data with specifications and approved shop drawings.

b. Inspect physical and mechanical condition.

c. Inspect anchorage, alignment, and grounding.

d. Verify that all maintenance devices are available for servicing and operating the breaker.

e. Inspect arc chutes.

f. Inspect moving and stationary contacts for condition, wear, and alignment.

g. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.

h. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.

i. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

j. Verify cell fit and element alignment.

k. Verify racking mechanism.

l. Confirm correct application of manufacturer's recommended lubricants.

2. Electrical Tests

a. Perform contact-resistance tests on each breaker.

b. Perform insulation-resistance tests.

c. Adjust Breaker(s) for final settings in accordance with Government provided settings.

d. Determine long-time minimum pickup current by primary current injection.

e. Determine long-time delay by primary current injection.
f. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function.

E. Grounding System

1. Visual and Mechanical Inspection

a. Inspect ground system for compliance with contract plans and specifications.

End of Section

SECTION 16437 – HIGH RESISTANCE GROUND AND MONITORING

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. The intent of this specification is to have the manufacturer furnish the equipment and material specified herein complete and operable.

B. All standard accessories to the equipment specified shall be supplied even if not specifically mentioned in this specification.

C. Material used in the fabrication of the specified equipment shall be new, unused, and of the highest quality available.

1.02 SCOPE

A. Work Included:

1. Furnish a high resistant ground system as detailed in these specifications. Any drawings or data sheets attached to the inquiry shall be considered part of this specification. The equipment shall be complete and operable.

2. Provide production tests and inspections as detailed in this specification.

3. To reasonably prevent the possibility of shipping damage, the manufacturer shall prepare the equipment for transportation to the jobsite and monitor the load out of this material.

4. It shall be the responsibility of the manufacturer to furnish all material, connections, splices, links, special tools, and information required to completely reassemble the switchgear in the field or to facilitate the installation of the switchgear when performed by an electrical contractor.

5. Guarantee the performance of the switchgear during a reasonable warranty period. This warranty shall, at a minimum, cover the equipment for eighteen (18) months from time of shipment or twelve (12) months from date of energization whichever occurs first.

6. Supply all drawings, documentation, and information as detailed.

1.03 CODES, STANDARDS AND CLASSIFICATIONS

The applicable codes and standards listed below should be considered as part of this specification. The latest revision in effect at time of inquiry shall apply for all standards referenced.

A. Underwriters Laboratories Inc. (UL)

B. Standard NMTR, NMTRT

C. Institute of Electrical and Electronics Engineers (IEEE)

1. Standard 32-1972: Requirements, Terminology, and Test Procedure for Neutral Grounding Devices.

2. Standard 142-1991: Grounding of Industrial and Commercial Power Systems.

D. International Electrical Commission (IEC)

1. Standard 529 and 144: Protection Degree for Enclosures

E. It shall be the manufacturer's responsibility to be knowledgeable of these standards and codes.

1.04 NEUTRAL GROUNDING RESISTOR

A. The neutral grounding resistor will consist of high grade chromium stainless steel or Nichrome elements and terminals of high corrosion resistance, double insulated, durable for long years of service, and having extremely high & stable electrical resistivity.

B. If more than one frame is required, series connections will be solid copper bus on grid style resistors, Teflon wire on wire-wound style resistors.

C. The resistor frame(s) will be mounted on standoff insulators with a rating equal to or greater than the line-to-neutral voltage.

D. The standard temperature rise will be 385°C.

E. The resistors shall be tapped at 2, 3, 4, 5, 6, 8 and 10 amps. The taps will be wired using Teflon insulated wire to a terminal block situated for safe access by the user to simplify coordinating the high resistance grounding system to a particular network's charging current.

1.05 ENCLOSURE FOR FREE-STANDING AND WALL MOUNT UNITS

A. The assembly shall be a NEMA 1 (indoor) or NEMA 3R (outdoor) enclosure housing both the control and resistor components.

B. The enclosure shall galvanneal steel and finished in ANSI-61 light gray powder-coat.

C. The resistor assembly shall be housed in a compartmentalized section of the enclosure to shield the controls from excessive heat. Ventilation shall be sufficient to properly cool the resistors in the event of a fault and maintain a safe environment for the controls.

D. Anti-condensation heater.

1. The NEMA 3R enclosure shall include an anti-condensation heater with adjustable thermostat suitable for use at rated system voltage as a standard.

2. The NEMA 1 enclosure may include an anti-condensation heater with adjustable thermostat suitable for use at rated system voltage when specified.

E. The enclosure will provide fused terminations for all three phases. These inputs will be used to identify which phase is grounded in the event of a fault and feed the optional control power transformer.

F. The enclosure shall have a dedicated ground bus in the bottom of the unit for connection to the user’s ground grid.

1.06 CONTROLS

A. All control circuits will operate on 120 VAC supplied via control power transformer. Controls shall be protected against electrical surges.

B. All control wiring will be rated at 600 VAC. Wiring must be sufficiently supported within the enclosure.

C. The high resistance neutral grounding equipment will contain the following equipment on the front of the unit as standard.

1. Fusible Disconnect Switch. The five pole disconnect switch (three phases, neutral to grounding resistor and neutral to sensing resistor) will be equipped with properly sized fuses (class CC).

2. Indicating Lamps. Three LED pilot lights indicating Normal status, Ground Fault in system and Pulsing in operation.

3. Horn to annunciate alarm conditions.

D. A digital interface unit with display screen containing the following functions.

1. Alarm View, Acknowledge and Clear Push-buttons.

2. System Test Push-button. The Test push-button shall be inoperable during a ground fault to prevent an accidental phase to phase fault. The push-button shall simulate a ground fault to measure proper operation of the HRG system.

3. System Reset Push-button

4. Lamp test feature to verify three lights listed above are functional

5. Pulse on/off push-button. The pulsing duration can be set by the user in the software.

6. Menu, Edit, Escape and Enter buttons to navigate the operating software and interface screens to program system parameters and alarm settings.

7. Software to Data Log / Trend system conditions. The unit should have an event log and an alarm log with date and time recording. The alarm log should record any ground fault events as well as the voltage and current readings. The event log should record any testing, pulsing activation, etc. A minimum of 200 records in either log is required.

8. An optional Ethernet port for communications when specified. This allows system parameters and conditions to be remotely accessed and viewed.

E. The unit shall monitor and annunciate the following conditions.

1. Under or over-current through the neutral.

2. Under or over-voltage on the neutral.

3. Specific phase faulted.

4. Failure in resistor path. The equipment shall include a Sensing Resistor Circuit to detect and annunciate breakdowns in the neutral through resistor to ground path.

F. The function to monitor neutral voltage and current will incorporate an adjustable time delay function to avoid spurious alarms. Additionally, the function will be tuned to detect only the fundamental frequency component to avoid false alarms.

G. The equipment shall include a pulsing feature to assist in locating faults. The pulsing cycle shall be adjustable by the user.

H. The unit shall be capable of measuring the system charging current by shorting one phase directly to ground. This shall be interlocked with the fault detection system to prevent measurement during a ground fault.

I. The optional portable ground detector will be a split-core type ammeter with a multiple range switch. The clamp must be capable of enveloping a minimum 6 inch diameter. A short circuiting switch should be provided, along with a carrying case. The handle must be insulated for use on 4,160 volt system.

1.07 MARKINGS

A. Wiring is to be numbered consistent with the wiring diagrams. Wire numbers are to be on sleeve type wire markers at each end of the wire.

B. Internal control panel components are to be identified with durable adhesive labels. Text may utilize an abbreviated legend, as long as that legend is identified on the wiring diagram.

C. Components on the front control panel are to be permanently identified.

D. A list of operating instructions is to appear on the front face of the control panel. These instructions are to cover normal, test, and fault conditions.

E. Each assembly must include a permanently attached nameplate specifying the following information.

1. Manufacturer
2. Volts Line-to-Neutral
3. Amps
4. Ohms
5. Seconds
6. Extended Time (if applicable)
7. Part Number or Drawing Number

1.08 INSPECTION AND PRODUCTION TESTING

A. Component bill of material shall be checked for proper quantity, description, and part number.

B. Physical dimensions shall be checked against approved drawings.

C. Equipment shall be subjected to a primary current injection procedure to determine proper operation of all current sensitive components.

D. Equipment shall be subjected to a primary voltage injection procedure to determine proper operation of all voltage sensitive components.

E. Complete assembly shall have a low frequency withstand (an AC high potential) test performed to assure insulation system integrity.

F. Manufacturer shall have in place a system of recording, correcting, and verifying resolution of discrepancies discovered during the inspection and testing process.

G. Certified production test reports indicating satisfactory completion of all inspection procedures shall be available upon request.

H. Upon request the equipment shall be made available for customer inspection prior to shipment.

I. Test reports for design tests shall be available upon request.

1.09 DOCUMENTATION

A. Drawings

1. Prior to fabrication the following drawings shall be submitted by the manufacturer for approval.

a. Front elevation view.

b. Base plan including mounting details, cable entry area, and door swing requirements.

c. Component bill of material indicating quantity, description, and part number.

d. Control or schematic diagram for each different unit.

B. Following the return of approval drawings the manufacturer shall prepare and submit wiring diagrams indicating physical location of secondary control components and the appropriate wiring connections. Each control wire will be labeled. Copies of these drawings shall be submitted to the customer, upon completion, for record.

C. After the return of approval drawings or after any change made to previously approved drawings, the manufacturer shall submit a record copy of any and all drawings that contained revisions.

D. After completion of the inspection and testing procedures the manufacturer shall submit a complete set of "as built" drawings. These drawings shall function as a record of the final construction of the equipment at the time it left the factory.

E. Drawings may be provided in any of the following forms as requested by the customer:

1. Full size plotted reproducible drawings size as required. "D size" measuring approximately 34" x 22", "C size" measuring approximately 22" x 17", "B size" measuring approximately 17" x 11", or "A size" measuring approximately 11" x 8½".

2. Digital files in the latest version of Autodesk AutoCAD.

3. Digital file format may be dwf, pdf, dgn, or dwg as specified.

F. Each drawing prepared by manufacturer shall show, at a minimum, the name, jobsite location, purchase order or contract number, and equipment identification number in addition to any information required by manufacturer.

1.10 OPERATING AND MAINTENANCE MANUALS

A. At time of shipment the manufacturer shall provide a copy of the operating and maintenance instructions.

B. Manuals shall contain a table of contents to allow for easy reference.

C. Operating and maintenance manual will be provided as pdf files on a CD for easy reference.

1.11 SPARE PARTS LIST

Upon completion of the engineering phase, a quotation for one (1) year's recommended spare parts shall be submitted.

END OF SECTION

SECTION 16438 – POWER QUALITY SOFTWARE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Furnish and install a complete Power Monitoring & Control System as detailed on the drawings and described in the specification.

B. The Power Monitoring Expert Software shall be manufactured by Schneider Electric (No Substitutions)

C. The Power Monitoring Expert (PME) software shall be a web-enabled monitoring system intended to monitor an entire electrical distribution infrastructure, from incoming utility feeds down to low voltage distribution points. All equipment shall be fully compatible with the existing Schneider Electric PME software.

D. The system shall be designed to monitor and manage energy consumption throughout an enterprise, whether within a single facility or across a network of facilities, to improve energy availability and reliability, and to measure and manage energy efficiency. All supplied equipment shall be fully compatible with the Schneider Electric PowerLogic system and shall support the following functions: onboard meter data logging, event recording with waveform capture, and remote controls and commands from the PMCS Server. All of these functions must be available without special interfaces, programming, or converters

E. The Software shall be a standard product offering with no custom programming required. The manufacturer shall demonstrate the system is not a prototype and that similar systems have been field installed and successfully operated for at least five years. The Power Monitoring Control System (PMCS) vendor shall have full responsibility for insuring the system performs as specified.

F. The Software shall provide multiple levels of user security.

G. Key features shall include:

1. Data acquisition for metering devices, sensors, and other intelligent electric devices.

2. Power Quality analysis (including harmonics, voltage sags/swells, transients and voltage and current sinusoids).

3. Power Quality Compliance reporting for international standards (IEC61000 4-30; EN50160).

4. Graphical displays of information.

5. Reporting tools with standard report templates.

6. Interactive historical data display and trending.

7. Real Time Data Tables with Standard Views.

8. Interactive Alarm Analysis with Standard Views.

9. Water, Air, Gas, Electricity, Steam (WAGES) monitoring and reporting.

10. Power Factor monitoring and reporting.

11. Interoperability with disparate devices and systems through OPC Client and OPC ServerThird Party Device Integration through Modbus RTU and Modbus TCP protocols Device Support.

H. The Software shall provide factory-tested, built-in support for at least 50 electrical distribution devices (energy and power meters, protection relays, circuit breakers, PLCs, etc.).

I. The Software device support shall be comprehensive and will include:

1. Ready-to-go, pre-engineered, interactive graphical display screens for viewing and analyzing real-time and historical device data

2. All registers pre-mapped to standard measurement names such that NO additional mapping of internal device registers is required to use any feature of The Software

3. Automatic upload of time-stamped onboard data logs, event strings and waveform captures to The Software WITHOUT ANY configuration.

1.02 GRAPHICAL MONITORING AND ANALYSIS APPLICATION

A. The Software shall provide a graphical monitoring and analysis application for power users (trained administrators, power system engineers, energy managers, facility managers, technicians, etc.) that provides a rich set of tools for WAGES energy analysis, Power Quality analysis, power system monitoring and control.

B. The graphical monitoring and analysis application shall be able to create a comprehensive set of linked hierarchical graphical diagrams showing all devices and their associated device specific diagrams in the power monitoring network WITH A SINGLE MOUSE CLICK (auto-diagram creation).

C. The graphical monitoring and analysis application shall support custom graphics/images and provide the ability to create graphical diagrams of the Power Monitoring system, including electrical one-line diagrams, facility maps, elevation view, meter drill-down screen, & custom application screens.

D. The graphical monitoring and analysis application shall provide support for Power Quality analysis and possess the following capabilities:

1. Plot PQ events on an ITIC/CBMEA curve or SEMI F47 curve.

2. Manual waveform capture.

3. Visualization/analysis tools for sinusoidal electrical waveforms including waveform overlay, zooming, calculations for RMS, peak, delta, harmonics spectrum bar charts and phasors diagrams.

E. The graphical monitoring and analysis application shall be capable of writing to device registers for applications such as resetting, triggering, toggling, switching, manual waveform capture, controlling remote devices and equipment, including breakers.

F. The graphical monitoring and analysis application shall allow application and HMI design engineers to create custom diagrams with linkages to device registers EVEN IF THE DEVICES ARE OFFLINE / DISABLED.

1.03 WEB-ENABLED APPLICATIONS

A. The Software shall provide a web client interface that supports the following web browsers:

1. Internet Explorer (versions 8, 9, 10).

2. Chrome (versions x).
3. Mac Safari (versions x).

B. The Software shall provide a web client interface that hosts a collection of web-enabled applications that all have the following in common:

1. Single sign-on capability. A user signs in once to use any of the web applications.

2. Multiple, simultaneous web browser sessions, allowing access by several people across the network.

3. The web applications shall NOT require the web browser to install and run an ActiveX control.

4. Support for Internet Explorer, Chrome, and Safari browsers.

C. The web client interface shall be easily customized and will allow:

1. Modification and creation of application launch buttons (appearance and order).

2. Any image or graphic to be inserted into the web client interface in lieu of the factory logos (e.g. corporate logos – customer icons) from any web client using only a browser.

3. The color scheme to be changed instantly from any web client using only a browser.

1.04 WEB-ENABLED DASHBOARDS

A. The Software shall have a web client interface that presents interactive, auto-updating dashboard views that may contain WAGES energy summary data, historical data trends, images and content from any accessible URL address.

B. Users shall be able to create, modify, view and share their dashboards (including graphics, labels, scaling, measurements, date ranges, etc.) from within the web-based application using only a browser and WITHOUT the need for a separate software application.

C. Dashboards may be easily created with configurable “drag & drop” Gadgets to show the following views:

1. Images from any web-based content.
2. Energy Consumption.
3. Energy Cost.
4. Energy Comparison.
5. Energy Savings.
6. Emissions.
7. Trends.

D. The Software shall allow individual “Dashboards” to be assigned to “Slideshows” that may run unattended, scrolling through the designated Dashboards at a configurable interval of time.

E. The Software shall allow an unlimited number of Dashboards and Slideshows to be created, saved and shared by any User of the system.

1.05 WEB-ENABLED GRAPHICAL SCREENS

A. The Software shall have a graphical web client application for monitoring real-time operational readings, (instantaneous values, min./max. values, alarm status, breaker status, etc.), AND analyzing historical data (for logged interval data, alarm/event strings, sag/swell voltage disturbance events [including disturbance direction] and voltage/current waveforms).

B. The web-enabled graphical screens shall be able to display system-level summary views, facility maps, plan views, floor layouts, electrical one-line diagrams, equipment summary pages, mimic displays, etc.

C. For every device type that is supported by The Software, there shall be a rich set of pre-built graphical diagrams that show all parameters which are available from the individual remote devices, including all metered values, load status, alarm status, energy data, device position and/or status, device data logs, waveform capture, sag/swell events, disturbance direction indication.

1.06 WEB-ENABLED REAL-TIME TABLES

A. The Software shall have a web client application that provides interactive, side-by-side visualization of real-time measurements in a tabular view to quickly compare device readings from multiple meters in the power monitoring network.

B. Users shall be able to create, modify, view and share their table views from within the web-based application using only a browser and WITHOUT the need for a separate software application.

C. The web-enabled real-time tables application shall have built-in functions that allow users to easily and instantly “filter out” measurements when viewing a table.

D. The web-enabled real-time tables shall support any physical or “virtual” device defined in the system.

E. Users shall be able to freeze the values when viewing a table.

F. Users shall be able to quickly convert a table into Excel format and save it as a .xsl file.

1.07 WEB-ENABLED ACTIVE ALARM VIEWER

A. The Software shall have a web client application that provides an intuitive, tabular display of all active alarms, historical alarms and events in the power system, such as over kW, breaker trips, and power quality disturbances.

B. The Active Alarm Viewer web client application shall indicate if a given Power Quality alarm has an associated waveform capture. It will also provide a link that will open the graphical homepage screen for the device that triggered the alarm.

C. The Active Alarm Viewer web client application shall have the following pre-built factory alarm views:

1. Recent Alarms (24 hours).
2. Active Alarms.
3. Unacknowledged Alarms.
4. Active and Unacknowledged Alarms.
5. Alarm History.

D. The Active Alarm Viewer web client application shall continuously monitor the status of all incoming alarms and provide dynamic, real-time views for “Active Alarms”. If a given alarm becomes “Active” (i.e. ON), it will be automatically and instantly displayed in the Active Alarms and Unacknowledged Alarms views. If a given alarm is no longer “Active” (i.e. OFF), it

will be automatically and instantly removed from the Active Alarms and Unacknowledged Alarms views.

E. Users with the appropriate access level shall be able to view and acknowledge alarms as well as review the event history of all devices in the system.

F. The Software shall contain an alarm annunciator indicator in the web client environment that will make an auditable sound and flash when new alarms are recognized by the system.

G. The alarm annunciator shall also continuously track and display the number of unacknowledged alarms.

1.08 WEB-ENABLED REPORT GENERATION

A. The Software shall provide a web-enabled reporting tool to view historical data in pre-formatted or user-defined report templates.

B. Users shall be able to create, modify, view and share their reports in the web reports interface.

C. The reporting tool shall provide standard pre-formatted report templates as follows:

1. Billing Report.
2. Energy Cost Report.
3. Load Profile Report.
4. System-wide Interactive Power Quality with CBEMA/ITIC Evaluation.
5. EN50160 Compliance Report.
6. IEC61000-4-30 Report.
7. 100 ms PQ Report.
8. Energy Period Over Period Report.
9. Energy Usage by Shift Report.
10. Tabular Report.
11. Trend Report.
12. Alarm and Event History Report.
13. System Configuration Report.
14. Hourly Usage Report.
15. Multi-Device Usage Report.
16. Single-Device Usage Report.
17. Data Export Report.

D. The reporting tool shall directly support the following output formats:

1. HTML.
2. PDF.
3. TIFF.
4. Excel.
5. XML.

E. The reporting tool shall provide the ability to create report “Subscriptions” to facilitate the automatic distribution of reports according to a schedule. Reports may be saved to a network location, printed or emailed.

1.09 EVENT-DRIVEN REPORTING

A. The Software shall support the ability to monitor incoming events and trigger the generation of a pre-configured report based on pre-specified event criteria.

B. The Software shall have an application that is designed for power users or system

deployment engineers for creating event monitoring “detection filters” so that when a specific event (or type of event) occurs, a designated report is generated and distributed automatically.

1.10 APPLICATION LOGIC ENGINE

A. The Software shall provide a graphical, object-oriented programming interface for creating system-wide, logical programs with arithmetic, XML data import, PC-based alarming and logging capabilities.

B. The application logic engine shall have a comprehensive set of functions such that deployment engineers may create custom applications programs such as weather or real-time price import, KPI calculations, energy units conversion, data aggregation, data normalization, data comparison, power loss calculations, power factor control, load shedding, etc.

1.11 LOGICAL DEVICES

A. The Software shall support “Logical” device definitions that provide user-friendly device and measurement names for inputs/outputs or channels on devices that represent a downstream device (in the case of PLCs and auxiliary inputs) or an individual circuit (in the case of multi-circuit devices).

B. A system deployment engineer shall be able to use a simple, structured file (containing logical device mappings and names) for the purpose of creating large numbers of logical devices in the system (bulk configuration) WITHOUT the need to configure each logical device manually.

1.12 HIERARCHIES

A. The Software shall support the concept of hierarchies such that historical data can be organized according to the domain of the Customer’s industry. For example, a Data Center could organize their hierarchies as Tenants/Racks/Circuits, PDUs/RPPs/Panels, or Buildings/Floors/Rooms.

B. The Software shall have the ability to track Hierarchy configuration changes over time and allow administrators to update the names in a given hierarchy at any time (even in the past) to ensure accurate reporting of associated data points. For example, report on energy consumption for a Tenant who has re-located, expanded, added or removed circuits during the billing period.

1.13 MODBUS INTEROPERABILITY

A. The Software shall have advanced communication capabilities for supporting Modbus communicating devices. The Software shall function as a Modbus master with the ability to read from and write to registers in Modbus devices for monitoring and control applications.

B. The Software shall provide an application that is designed for system deployment engineers for creating Modbus device definitions (device drivers) so that 3rd party devices that support Modbus protocol may be easily integrated into the power monitoring system.

1.14 OPC (OLE FOR PROCESS CONTROL) INTEROPERABILITY

A. The Software shall be OPC DA 2.0.1 compliant (as per the OPC Foundation Compliance Testing process) for OPC Server and OPC Client data sharing applications amongst OPC compliant systems.

B. The Software shall provide default OPC Server tag mappings for all of its natively supported

device types WITHOUT the need to select, configure or program the mapping of device registers to OPC tags.

C. The Software shall provide a flexible means to add or change OPC mappings and shall support the ability to add custom measurements. Extract, Transform and Load (ETL).

D. The Software shall support Extract, Transform and Load (ETL) data log file transfer mechanisms. It will be able to import data log files into its historical database and export data log files from its historical database for system data sharing and file transfer applications (e.g. manual data entry, offline device data import, push data to the cloud or 3rd party system, etc.).

E. The Software shall provide an ETL application that is designed for system deployment engineers for establishing log data file import-export mappings and schedules so that historical data can be incorporated into or exported from the power monitoring system via file transfer (.csv, .xml, etc.)

1.15 WEB SERVICES SOFTWARE INTEGRATION

A. The Software shall provide a Web Services interface for machine-to-machine interactions with other application software systems. The web service interface shall have the following characteristics:

1. Based on SOAP (Simple Object Access Protocol) protocol specification.

2. Provide a Web Services Description Language (WSDL) based, machine-readable description.

3. Allow access to real-time, historical (i.e. time stamped), and alarm/event type data.

4. Provide the ability to acknowledge alarms by authenticated and authorized clients.

5. Provide digest authentication functionality.

6. Provide the ability to be enabled/disabled.

B. The Software shall be compatible and integrate with Schneider Electric Ecostruxure solutions.

1.16 COMMUNICATIONS SUBSYSTEMS

A. The Software shall support multiple communications network topologies including Ethernet/TCP, serial RS-485/RS-232, and Modem dial-up connections.

B. The Software shall have the capability to provide time-synchronization signals over an Ethernet network with 16ms accuracy.

C. The Software shall have the capability to communicate simultaneously with multiple devices, including devices that are on different physical communications channels.

D. The Software shall scale to communicate from 1 to 1000’s of devices.

E. The Software shall have the ability to retrieve logged data (interval data, event data, waveform data) from natively supported devices in the system automatically WITHOUT any configuration (of upload jobs, log tasks, etc).

F. The Software shall have the ability to accept or reject duplicate data entries into the database.

1.17 OFFLINE CONFIGURATION

A. The Software shall support the ability to develop custom graphics screens and application logic programs using device register map files EVEN WHEN DEVICES ARE OFFLINE / DISABLED so that application engineers and HMI design engineers can develop customer projects easily without having to be connected to live devices.

1.18 DATA STORAGE

A. The Software shall be designed to use Microsoft SQL Server for its database engine and data storage.

B. The Software shall support having the database engine installed on the same computer or a separate dedicated Database Server computer.

C. The Software shall include a “default” database engine option (e.g. SQL Server Express Edition) with its media. During the installation of the Software, if the “default” database engine option is selected, it shall be installed by the Software installer WITHOUT having to acquire and install it separately.

D. The Support Matrix for Operating System & SQL server:

32-bit Windows Operating Systems	32-bit Microsoft SQL Server Editions	Standalone Server	Distributed Database Server
Windows 7 Professional/Enterprise, SP1	SQL Server 2008 R2 Express, SP2	Yes	No
	SQL Server 2008 R2 Standard/Enterprise, SP2	Yes	No
	SQL Server 2012 Express, SP1	Yes	No
	SQL Server 2012 Standard/Enterprise, SP1	Yes	No
Windows Server 2008 Standard/Enterprise, SP2	SQL Server 2008 R2 Express, SP2	Yes	No
	SQL Server 2008 Standard/Enterprise, SP3	Yes	Yes

64-bit Windows Operating Systems	64-bit Microsoft SQL Server Editions	Standalone Server	Distributed Database Server
Windows 7 Professional/Enterprise, SP1	SQL Server 2008 R2 Express, SP2	Yes	No
	SQL Server 2008 R2 Standard/Enterprise, SP2	Yes	No
	SQL Server 2012 Express, SP1	Yes	No
	SQL Server 2012 Standard/Enterprise, SP1	Yes	No
Windows Server 2008 Standard/Enterprise SP2, and R2 SP1	SQL Server 2008 R2 Express, SP2	Yes	No
	SQL Server 2008 R2 Standard/Enterprise, SP2	Yes	Yes
Windows Server 2012 / R2 Standard/Enterprise	SQL Server 2012 Express, SP1	Yes	No
	SQL Server 2012 Standard/Enterprise, SP1	Yes	Yes

1.19 OPERATING ENVIRONMENT

A. The Software shall be installed on one of the following Microsoft Windows operating systems:

1. Windows 7 (32-bit) Professional/Enterprise Editions
2. Windows 7 (64-bit) Professional/Enterprise Editions
3. Windows Server 2008 (32-bit) Standard/Enterprise Editions
4. Windows Server 2008 (64-bit) Standard/Enterprise Editions
5. Windows Server 2008 R2 (64-bit) Standard/Enterprise Edition

The minimum recommended size for the system with 50 devices is shown below:

System[1]	Devices	Users	Server Recommendations	Years of Logging[2]	OPC Tags	VIP Tags[3]
B1	≤ 50	≤ 5	**Computer Type**: Desktop **OS**: Windows 7 (64-bit) **SQL**: 2012 Express SP1 **CPU**: Intel Core i3 (2 core), or better **RAM**: 2+ GB **HDD**: 500+ GB	~4 years(10 GB)	1000	250
B2	≤ 100	≤ 5	**Computer Type**: Desktop **OS**: Windows 7 (64-bit) **SQL**: 2012 Express SP1 **CPU**: Intel Core i3 (2 core), or better **RAM**: 4+ GB **HDD**: 500+ GB	~2 years(10 GB)	1000	250
B3	≤ 100	≤ 5	**Computer Type**: Desktop **OS**: Windows 7 (64-bit) **SQL**: 2012 Standard SP1 **CPU**: Intel Core i3 (2 core), or better **RAM**: 4+ GB **HDD**: 500+ GB	~6 years(30 GB)	1000	250
A1	≤ 100	≤ 15	**Computer Type**: Workstation **OS**: Windows 7 (64-bit) **SQL**: 2012 Standard SP1 **CPU**: Intel Xeon E56xx (4 core), or better **RAM**: 8+ GB **HDD**: x2 500+ GB	<6 years(30 GB)[4]	5000	1500

[1] Basic or Advanced system (for example, B3 denotes the third of the basic systems in a larger order of magnitude).
[2] Years of data in the database is calculated based on a 10 GB database for SQL Server Express and 30 GB (or larger) for SQL Server Standard edition.
[3] VIP "tags" are measurements used for alarming and/or logging.
[4] Based on the following device mix: 10% advanced; 20% intermediate; 70% basic/entry.
It is recommended to calculate the ION_Data size and number of years of logging.

1.20 SYSTEM ADMINISTRATION

A. The Software shall provide a comprehensive Administrative interface for power users or system deployment engineers that supports the following functions:

1. Configure connection schedules and manage modem connections.

2. Add devices to the system and manage their communication settings.

3. Manage device names and measurement mapping.

4. View and manage software system events.

5. Administer database management tasks (backup, archiving and trimming).

6. Administer groups and user accounts.

B. The Software shall continue to function WITHOUT ANY DISRUPTION (including communications, logging, alarming) and will REMAIN ONLINE during the following processes:

1. Adding, modifying or removing devices in the system.

2. Creating, modifying or removing graphical diagrams, dashboards, tables, reports.

3. Creating, modifying or removing application logic programs in the Application Logic Engine.

1.21 LANGUAGE SUPPORT/INTERNATIONALIZATION

A. The Software shall be developed for internationalization and support regional settings such that it may be localized into any language.

B. The Software shall support the following languages by default:

1. Chinese (Simplified).
2. Chinese (Traditional).
3. English.
4. French.
5. German.
6. Italian.
7. Russian.
8. Spanish.

1.22 DOCUMENTATION

A. The Software shall provide documentation for helping users learn how to use the Software that is accessible from within the Software from any client computer (Web clients or Engineering clients).

B. The Software shall also provide several PDF-formatted documents related to the installation and use of the Software on the Software media (DVD).

1.23 SYSTEM STARTUP & TRAINING

A. Onsite Startup and training of the Power Monitoring Control System shall be included in project bid.

B. Startup shall include a complete working demonstration of the PME software with simulation of possible operation conditions that may be encountered.

C. Training shall include any demonstration and hands on exercises necessary to enable electrical operations personnel to assume full operating responsibility for the PME System after completion of the training period.

D. The project shall include at minimum 5 days of startup assistance and 2 days of onsite training (2 trips).

E. The power monitoring shall provide a full time telephone technical help center for customers.

F. A one year support agreement shall be provided including:

1. Toll Free PMCS Technical Support.
2. Free PMCS Software Version Upgrades.
3. Two-for-One Training Discounts.
4. Annual Renewable Agreement.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION (NOT USED)

END OF SECTION

SECTION 16440 - MOTOR CONTROL

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Contractor shall furnish and install motor control equipment as specified herein and as shown on the Drawings.

1.02 SUBMITTALS

A. Motor control equipment shall be new and the equipment of one manufacturer. Each component is specified by a particular trade name; however, this does not relieve the Contractor of the responsibility of submitting descriptive literature and Shop Drawings for review of all components.

B. Shop drawings, including layout drawings, complete schematic and composite wiring diagrams, control circuit wiring diagrams and descriptive literature shall be submitted to the Engineer for review. **Service manuals shall be submitted on all equipment and shall be bound in 3-ring loose leaf binders.** The manuals shall also include information on accessories such as timers, etc., built in the control center.

1.03 SERVICE OF MANUFACTURER'S REPRESENTATIVE

A. The Contractor shall provide the services of a qualified manufacturer's technical representative who shall adequately supervise the installation and testing of all equipment furnished under this Contract and instruct the Contractor's personnel and the Owner's operating personnel in its maintenance and operation as outlined elsewhere in Division 1. The services of the manufacturer's representative shall be provided for a period of not less than as follows:

1. One trip of one (1) working day during installation of the equipment for each motor control center or as required.

2. One trip of one (1) working day after acceptance of the equipment.

3. One trip of one (1) working day during the warranty period.

B. Any additional time required to achieve successful installation and operation shall be at the expense of the Contractor. The manufacturer's representative shall sign in and out at the office of the Engineer's Field Representative on each day he is at the project.

1.04 TRAINING

A. The Contractor shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory trained specialists who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section and Section 16050.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Control Equipment

1. “Square D” Model 6 Intelligent Series, “Allen Bradley” Intellicenter, or approved equal.

B. Timers

1. “Allen Bradley”, or approved equal

2.02 MOTOR CONTROL CENTERS (MCC)

A. General

1. Quality of built-in transformers, starters, lighting panelboards, timers, etc. shall be as written elsewhere in this Division unless otherwise noted.

2. Provide “Intelligent” series of MCC’s with network communications via Ethernet/IP.

3. Motor Control Center(s) shall consist of one or more enclosed vertical sections joined together to form a rigid, free standing assembly. The construction of the Motor Control Center shall meet the requirements set forth by Underwriters’ Laboratories publication UL-845, NEMA publication number ICS-2-322, the National Electrical Code, and color coded.

4. The structure shall be UL listed and labeled as service equipment if applicable. All sections shall bear UL labels.

5. Enclosures shall be NEMA 1 unless otherwise indicated, and each control center suitable for connection to an available fault current of 65,000 RMS symmetrical amperes unless otherwise indicated on the Drawings.

6. Provide arc-resistant design. Arc Resistant Low Voltage MCCs shall be tested, rated, and labeled in accordance with the requirements of IEEE C37.20.7. They shall also meet the testing requirements of IEEE C37.20.7-2007 for type 2 Accessibility.

7. Provide windows to allow thermal testing without opening MCC doors on the mains and tie breakers.

8. Provide remote racking. Plug-in units shall have the capacity of withdrawing the power stabs from the vertical bus, allowing the primary voltage to be disconnected with the unit door closed. A remote operating device shall be supplied to allow the connection and disconnection of the power stabs with the door closed.

B. Construction

1. Vertical Sections

a. Vertical sections shall support the horizontal and vertical buses, combination starter units, covers and doors, and shall be designed to allow for easy rearrangement of units by the purchaser. Vertical sections shall have structural supporting members formed of a minimum of 13 gauge hot-rolled steel. All finished surfaces shall be blemish-free. Where needed, reinforcement structural parts shall be of 10-gauge steel to provide a strong rigid assembly. Each section shall be 90 inches high and shall have 7 gauge steel, 3 inch high removable lifting angle and two 1 1/2 inch high base channels. Complete control center line-ups shall be divided into shipping splits no wider than approximately 60 inches. The lifting angle shall be provided on the top of each shipping split and shall extend the entire width of the shipping split. Lifting angles shall be designed to support the entire weight of the MCC section. Base channels shall be provided with holes to permit bolting the Motor Control Center(s) to the floor. The entire assembly shall be constructed and packaged to withstand all stresses induced in transit and during installation.

b. Motor Control Centers shall be designed so that matching vertical sections of the same current rating and manufacture can be added later at either end of the line-up without use of transition sections and without difficulty or undue expense.

Removable end closing plates shall be provided to close off openings on the end of the Motor Control Center line-up. A removable top plate shall be provided on each vertical section and shall be of one-piece construction for added convenience in cutting conduit holes. The design shall allow use of the standard conduit entrance area without significant sag or deformation of the top plate.

c. Vertical sections shall be designed to accommodate plug-on units in front-of-board or back-to-back construction as shown on Contract Drawings. Vertical sections housing plug-on units shall be 20 inches wide and shall be 20 inches deep. Wider sections will be permitted only for bolted connection type units not fitting the 20-inch wide sections. Unit mounting area shall be divided into 1/2 space factor divisions, each approximately 6 inches. NEMA Size 1 and 2 combination starter units shall use only 1 space factor, or 12 inches, of unit mounting space. Vertical sections shall allow for up to 7 space factors of unit mounting space. Removable blank plates shall cover all unused unit-mounting spaces. Blank plates shall be flanged on all 4 sides and shall be mounted with captive screws. Blank space shall be equipped for future use.

d. Vertical sections shall be provided with both horizontal and vertical wireways. Sufficient clearances shall be provided in the horizontal wireway so that no restriction is encountered in running wires from the vertical to horizontal wireway. Wireways shall be in accordance with the wireway sections contained in this document.

2. Horizontal Wireways

a. Horizontal wireways shall be provided in the top and bottom of each vertical section as indicated in the Contract Drawings and shall be arranged to provide full-length continuity throughout the entire assembly. The top horizontal wireway shall have a cross sectional area of not less than 20 square inches with openings between sections of not less than 11/2 square inches. The bottom horizontal wireway shall extend through the length and depth of the vertical sections and shall also be provided with openings of not less than 11/2 square inches to allow for full length continuity throughout the entire assembly. The bottom horizontal wireway height shall be not less than 9 1/4 inches. Covers for all wireways shall be equipped with captive type screws to prevent loss of hardware during installation. All wireways shall be isolated from the bus bars.

3. Vertical Wireways

a. A vertical wire trough shall be located on the right -hand side of each vertical section and shall extend from the top horizontal wireway to the bottom of the available unit mounting space. Each vertical wire trough shall have a cross sectional area of not less than 19 square inches and shall be isolated from the bus bars to guard against accidental contact. A separately hinged door having captive type screws shall cover the vertical wire trough to provide easy access to control wiring without disturbing control units.

b. Reusable wire ties shall be furnished in each vertical wire trough for the purpose of grouping and securely holding wires in place for a neat and orderly installation.

4. Busbars

a. A continuous main three-conductor horizontal bus shall be provided over the full length of the control center. A fully rated horizontal neutral bus (1200 ampere maximum) shall also be supplied over the full length of the Motor Control Center. When necessary, the bus shall be split to allow for ease in moving and handling. Splice bars will be supplied to join the bus wherever a split has been made. All splice connections shall be made with at least two bolts and shall employ the use of Belleville washers in the connection. Horizontal bus bars shall be mounted edgewise and supported by insulated bus supports.

b. For distribution of power from the main horizontal bus to each unit compartment, a three-phase vertical bus shall be provided. The vertical bus shall be firmly bolted to the horizontal bus for permanent contact.

c. The main horizontal and vertical buses shall be made of copper and the entire length shall be electrostatically tin plated to provide maximum protection to the bus bars from normal or adverse atmospheric conditions.

d. Bus supports shall be formed of high strength glass reinforced alkyd material. Bus supports shall have generous surface clearances in the vertical plane to shed dust and maintain dielectric integrity. Bus supports and insulators shall be red to indicate proximity of energized bus parts.

e. Horizontal and vertical buses shall have continuous current ratings adequate to handle all loads as shown on the one line diagram in the Contract Drawings. Continuous current ratings shall be in accordance with temperature rise specifications established by UL, ANSI, and NEMA standards.

f. A copper ground lug shall be provided in each incoming line vertical section capable of accepting a #8 to 250 MCM cable. A horizontal copper grounding bus shall be provided in each section of the Motor Control Center. Horizontal grounding bus shall run continuously throughout the control center except where splits are necessary for ease of shipment and handling in which case splice bars shall be provided. Grounding bus shall be tin plated copper and have a cross sectional area equal to 28% of the main horizontal bus cross sectional area. Horizontal ground bus shall be located at the bottom of the Motor Control Center.

5. Bus Barriers

a. Insulated horizontal and vertical bus barriers shall be furnished to reduce the hazard of accidental contact with the bus. Barriers shall have a red color to indicate proximity of energized buses. Vertical bus barriers shall have interlocking front and back pieces to give added protection on all sides and shall segregate the phases to reduce the possibility of accidental “flash over”. Small, separate openings in the vertical bus barriers shall permit unit plug-on contacts to pass through and engage the vertical bus bars. Bottom bus covers shall be provided below the vertical bus to protect the ends of the bus from accidental contact with fish tapes or other items entering from the bottom of the enclosure.

b. Isolation of unused stab openings shall be accomplished by use of a manual shutter to close off the stab opening. These shutters shall be attached to the structure so that when they are removed (to allow a stab connection) they are retained in the structure and are readily accessible for use should a plug-in unit be removed from the motor control center.

6. Main Incoming Lug Compartment

a. A front accessible main lug compartment shall be provided with suitable main lugs to accommodate the number of cables per phase as indicated on the Contract Drawings. The compartment shall be located in the top most or bottom most unit space of the section to accommodate the user’s cables entering the Motor Control Center as indicated on the Contract Drawings. The main incoming lug compartment shall be covered by a hinged door for maintenance access. This door shall be held closed with captive type screws to discourage unauthorized access. (A unit door padlock attachment shall also be provided to lock the door in the closed position with one 5/16 inch diameter shackle padlock. This attachment shall also accept a meter type seal.)

7. Units

   a. Combination starter units shall consist of Size 1 minimum full voltage magnetic starters, autotransformer reduced voltage starters, molded case magnetic-only circuit breakers, and auxiliary control devices, as required and/or shown on the one-line and elementary diagrams. Pilot light assemblies (push-to-test) shall be 30 mm LED. All auxiliary equipment, except that which is specified for mounting on the door, shall be mounted within the compartment. All units shall be provided with unit doors, unit support pans, unit saddles and unit disconnect operators as outlined in this Specification. Each unit compartment shall be enclosed and isolated from adjacent units, buses and wireways except for openings for conductor entrance into units. Units shall be designed and constructed so that any fault will be localized within the compartment. All units shall be UL listed for minimum of 65,000 amperes RMS symmetrical fault withstand ability unless otherwise indicated on the Drawings.

   b. Plug-on combination starter units of the same NEMA size and branch feeder units of the same trip size shall be readily interchangeable with each other. It shall be possible to withdraw each plug-on unit to a de-energized position with the unit still being supported by the structure. It shall be possible to lock the unit in this position with one padlock.

   c. Full voltage non-reversing combination starter units shall have the following minimum space factor requirements, shall be provided with plug-on connections and shall be provided with ample space for customer wiring room:

	Circuit Breaker Space Factor
Size 1	1
Size 2	1
Size 3	1 1/2
Size 4	2

8. Unit Plug-On

   a. For convenient unit connection to bus bars, unit plug-on contacts shall be provided on the following units:

      1) For circuit breaker type units; full voltage starters, size 4 and smaller; auto-transformer reduced voltage starters, size 4 and smaller; part winding reduced voltage starters, size 4PW and smaller; branch circuit units, 225 ampere and smaller.

   b. The plug-on connection for each phase shall be of a high quality two- point connection and shall be designed to tighten around the vertical bus bar during a heavy current surge. For trouble-free connections, the plug-on fingers shall be silver plated and coated with a compound to assure a low resistance connection. Contact fingers shall be of a floating and self-aligning design to allow solid seating onto the vertical bus bars.

   c. Starters NEMA size 4 and larger shall bolt directly to the vertical bus bars, circuit breakers rated higher than 225 amps shall also bolt directly to the bus bars.

9. Unit Doors

   a. Each unit shall have a door securely mounted with rugged concealed-type hinges which allow the door to swing open a minimum of 112° for unit maintenance and withdrawal. Provide observation windows where appropriate for thermal testing and interior observation. Doors shall be fastened to the structure so that they remain in

place when a unit is withdrawn and may be closed to cover the unit space when the unit has been temporarily removed. Doors shall be held closed with captive type screws which engage self-aligning cage nuts. These screws shall provide at least two threads of engagement to hold doors closed under fault conditions. Each unit door shall be interlocked with its disconnect mechanism to prevent the door from opening when the unit is energized. A defeater mechanism shall be provided for defeating this interlock by authorized personnel. Removable door panels held with captive type screws shall be provided on starter unit doors for mounting push buttons, selector switches or pilot lights. Blank door panels capable of accepting future pilot devices shall be furnished when pilot devices are not originally specified for starter units. Each starter unit door shall house an external low-profile overload reset button for resetting the overload relay in the event of tripping.

10. Unit Support Pan

    a. Each plug-on unit shall be supported and guided by a tilt and lift-out removable pan so that unit rearrangement can be easily accomplished. For easy unit installation and rearrangement, transfer of this unit support pan from one location to another shall be accomplished with ease after the control unit and door have been removed.

11. Unit Saddles

    a. Each plug-on unit shall have a saddle of 14 gauge hot rolled steel designed and constructed to physically isolate the unit from the bus compartment and adjacent units. Saddlers shall be equipped with captive, self-aligning mounting screws which shall hold the unit securely in place during shipment. Flanged edges shall be provided on each saddle to facilitate unit removal.

12. Disconnect Operators

    a. An external operator handle shall be supplied for each switch or breaker. This mechanism shall be engaged with the switch or breaker at all times regardless of unit door position to prevent false circuit indication. The operator handle shall be color coded to display red in the “ON” position and black in the “OFF” position. The operator handle shall have a conventional up-down motion and shall be designed so that the down position will indicate the unit is “OFF”. For added safety it shall be possible to lock this handle in the “OFF” position with up to three padlocks. The operator handle shall be interlocked with the unit door to prevent switching the unit to “ON” while the unit door is open. A defeater mechanism shall be provided for the purpose of defeating this interlock by a deliberate act of an electrician should he desire to observe the operation of the operator handle assembly or the unit components. Operators shall not be higher than 6'-6" above finished floor elevation, as installed.

13. Wiring

    a. The motor control center wiring shall be NEMA Class II, Type B.

    b. All wiring to the terminal strips from outside the MCC shall be made with spade type terminals of the proper size and rating for the wire used. Pull apart terminal blocks shall be provided in unit spaces of motor starters that contain field wiring energized from a remote source to comply with NEC Article 430-74.

    c. All control wiring shall be No. 14 AWG (minimum) labeled at each end in accordance with the wiring numbers shown on the accepted shop drawings. Power wiring shall be sized to suit the maximum horsepower rating of unit; No. 12 AWG (minimum). Wiring shall be type MTW rated for 105^{o} C. Wire color coding shall be red for control and black for power. Wire numbers shall not be repeated in a motor control center.

14. Finish

    a. The finish shall be manufacturer's standard gray enamel applied over a rust inhibiting phosphate primer.

15. Optional Modifications and Accessories

    a. Additional modifications and accessories shall be as listed and specified on the Contract Drawings.

16. Identification

    a. A control center identification nameplate describing section catalog numbers and characteristics shall be fastened on the vertical wire trough door of every section. Each control center unit shall have its own identification nameplate fastened to the unit saddle. These nameplates shall have suitable references to factory records for efficient communication with supplier. Each control center unit shall also have an engraved Bakelite nameplate fastened to the outside of each unit door inscribed as written on the Contract Drawings for ease in identification and for making changes when regrouping units. An overall structure nameplate is also required.

17. Metering

    a. All voltmeters, ammeters, wattmeters, current transformers, potential transformers and phase selector switches shall be furnished as shown on the Contract Drawings. Meter accuracy shall be $\pm$ 1 percent. Solid state metering shall be as specified this section.

18. Surge Protective Devices

    a. Specification Section 16280 – Surge Protective Devices for motor control center SPD requirements.

19. Ethernet IP Communications

    a. The MCC shall have Ethernet wiring incorporated into its design.

        1. The MCC shall have factory installed industrial Ethernet cabling incorporated throughout the the entire lineup.

        2. Each motor starter, electronic overload relay, power monitor, AC drive, and soft starter unit in the MCC shall be supplied with a means to communicate via EtherNet/IP network.

        3. Plug-in units should be able to move around without impacting the network.

        4. Maintenance activities should be able to be performed without impacting the network.

    b. Industrial Ethernet Switch.

        1. The MCC shall have managed industrial Ethernet switch(s) with Ports to connect each EtherNet/IP enabled device.

        2. Ethernet Switches shall be provided with spare ports to accommodate network expansion and future plug-in unit inserts.

        3. The managed industrial Ethernet switch shall deliver optimal network security, network resiliency (if needed), and flexibility. The functionality should include

port based control/prioritization, switch-level ring support, VLAN segmentation, and other Layer-2 switch features.

4. The managed industrial Ethernet switch shall have the ability to include, if needed, Gigabit ports, CIP Sync functionality, Network Address Translation (NAT) and an Industrial SD Card.

5. The managed industrial Ethernet switch shall include redundant terminal blocks for connection of a 24VDC UPS (26Ah, 12V battery powered) mounted in the MCC.

C. Power Supplies.

1. Power supplies shall provide 24V DC for the devices that require it.

2. The MCC manufacturer shall check the user's design to ensure that adequate power supplies have been specified to conform with network requirements.

3. Power supply output shall be rated 8 A, 24V DC.

4. Power supplies shall be Allen-Bradley Bulletin 1606-XLSDNET8 or approved equal.

5. Power supplies unit shall be provided with a buffer module to provide a minimum of 500 ms ride-through at full load.

6. Buffer modules shall be Allen-Bradley Bulletin 1606-XLBUFFER or approved equal.

7. Up to four (4) 24V DC adapters shall be provided:

a. In each vertical wireway of standard sections to simplify installation, relocation and addition of plug-in units.

b. Each 24V DC adapter in the vertical wireway shall be connected to the power supply.

D. Industrial Ethernet Cable.

1. Industrial Ethernet Cable Ratings

a) The industrial Ethernet cable shall be 600V UL Category 5e PLTC rated.
b) The use of a 300V and or AWM rated cable is not acceptable.
c) Ethernet Switch to Device cables labels shall be located on both ends to specify where the cable is coming from and going to.

E. Layout – Fixed-Mount Switch Unit

1. The managed industrial Ethernet Switch shall be mounted in a fixed-mount, Switch Unit in the top or bottom of the section.

2. The industrial Ethernet cable shall connect each switch to one another in a linear topology

3. The Switch Unit shall be provided with a locking latch.

4. The Switch Unit shall be provided with a door mounted viewing window.

F. Layout – Homerun Connections

1. An industrial Ethernet cable shall be routed from the fixed-mount, Switch Unit directly to the EtherNet/IP device in each unit.

    i. The industrial Ethernet cable shall be routed through the top or bottom horizontal wireway and transition through the vertical wireway directly to the EtherNet/IP device.

    ii. The industrial Ethernet cable shall be secured to vertical wireway tie bars.

2. The EtherNet/IP device within each unit shall be factory connected to the industrial Ethernet switch directly by using a 600V – UL rated Category 5e PLTC rated industrial Ethernet cable.

G. EtherNet/IP Interface for Motor Starter Units.

1. Motor starter units shall have an electronic overload relay that incorporates the following features:

    a) Built-in EtherNet/IP communication.

    b) Overload relay powered by 120VAC.

    c) LEDs for status indication.

    d) Test/Reset button.

    e) Selectable trip of NEMA Class 5 to 30. Unless indicated, the trip class shall be set for NEMA Class 20 operation.

    f) Up to six (6) inputs and three (3) outputs of direct I/O. Additional I/O can be provided with an add-on module to the overload relay. Input voltage shall match the overload relay power voltage.

    g) Protective functions.

        i. Functions shall provide a programmable trip level, warning level, time delay, and inhibit window.

        ii. Protective functions shall include Thermal overload, Phase loss, Stall, Jam, Underload, Current imbalance, Remote trip, and PTC thermistor input.

        iii. Ground fault protection is required.

            a. If ground fault protection is required, the protection range shall be 20 mA to 5 A**.**

        iv. PTC Thermistor input is required for any motor over 15HP.

        v. Voltage protection is not required

            a. Input fusing shall not be used on NEMA 3 and smaller starters.

    h) Current monitoring functions shall include phase current, average current, full load current, current imbalance percent, percent thermal capacity utilized, and ground fault current (if required).

    i) Voltage, energy, and frequency measuring capabilities shall be included when voltage protection is required.

j) Diagnostic information shall include device status, warning status, time to reset, trip status, time to overload trip, and history of last five trips.

k) Preventive maintenance information shall include Allowable starts per hour, required Time between starts, Starts counter, Starts available, Time until next start, total operating hours, and elapsed operating time.

l) Overload relay shall include an on-board logic processor to allow basic logic to be performed within the overload relay based on network data and the status of the inputs to the overload relay.

m) The overload relay shall support the following CIP messaging types: Polled I/O messaging, Change-of-state/cyclic messaging, Explicit messaging, Group 4 offline node recovery messaging, and Unconnected Message Manager (UCMM).

n) The overload relay shall provide the following functions to minimize network configuration time: Full parameter object support, Configuration consistency value, and Add-on Profile.

2. The overload relay shall be Allen-Bradley E300™ model or approved equal

H. EtherNet/IP Interface for Variable Frequency AC Drives and Solid-State Reduced Voltage Motor Controllers.

1. The EtherNet/IP communication interface shall be supplied to allow for communication between the solid-state component and the Ethernet network

I. EtherNet/IP Interface for Other Units.

1. Provide an EtherNet/IP interface for other units as indicated on the contract drawings

2. Refer to the contract drawing wiring diagrams for points to be monitored

J. Programming and Testing.

1. The MCC manufacturer shall load the IP Address and Subnet Mask into each unit

2. The IP Address shall be as indicated on the contract drawings or as provided by the contractor

3. The MCC manufacturer shall test the MCC to ensure that each unit communicates properly prior to shipment

4. Each unit shall have a label showing the IP Address for the devices within it

5. The MCC manufacturer shall provide a disk containing applicable electronic data sheet (EDS) files for the EtherNet/IP devices

K. Starters and Overcurrent Protective Devices

1. Magnetic Starters

a. Magnetic starters shall be furnished in all combination starter units unless otherwise indicated on Contract Drawings. Starter Sizes 1 through 4 shall employ the use of a bell-crank lever design to transform vertical action of the armature into horizontal action of the contact carriers and thus minimize contact bounce and produce extra long contact life. Thermal overload relays on starters shall be ambient temperature compensated bimetallic type with selector for either auto or manual reset. Overload

heater units shall be provided in each starter unit. Overload relay heater schedules shall be provided on each starter unit.

2. Circuit Breakers

   a. Molded case circuit breakers shall be furnished in all starter and branch feeder units using circuit breakers as a disconnect means. All circuit breakers will have a push-to-trip test feature for testing and exercising the circuit breaker trip mechanism.

3. Starters shall conform to requirements listed under individually mounted Motor Control Devices, hereinafter.

L. Lighting Panelboards

1. Lighting panelboards shall be as specified in other section of this Division. Lighting panelboard unit doors shall be held closed with captive latches that may easily be operated without the use of tools, i.e., wing nuts, handle, etc.

M. Transformers

1. 480 volt primary, 120/240 volt or 120/208 volt secondary transformers shall be as specified in other sections of this Division.

N. Electronic Circuit Monitors

1. Circuit Monitor Installation

   a. Electronic circuit monitors shall be installed by the equipment manufacturer for all circuits as indicated on the Contract Drawings.

   b. All control power, CT, PT, and communications wire shall be factory installed and harnessed within the lineup.

   c. Where external circuit connections are required, terminal blocks shall be provided and the manufacturer's shop drawings must clearly identify the interconnection requirements, including wire type, to be used.

   d. This equipment shall be Square D Power Logic, Allen-Bradley EC3 Plus, or approved equal.

2. Circuit Monitor Characteristics

   a. The electronic circuit monitors shall accept inputs from industry standard instrument transformers (120 VAC secondary PTs and 5A secondary CTs).

   b. The current and voltage signals shall be digitally sampled at a rate high enough to provide accurate rms sensing and valid data for waveform analysis beyond the 30th harmonic (fundamental of 60 Hz).

   c. All setup parameters required by the circuit monitors shall be stored in nonvolatile memory (no battery backup) and retained in the event of a control power interruption.

   d. The circuit monitor shall also maintain, in nonvolatile memory, a maximum and minimum value for each of the instantaneous values reported, as well as the time and date of the highest peak for all of the peak demand readings.

   e. The circuit monitors shall be equipped with an integral LED display to provide local access to metered quantities.

f. The following instantaneous readings shall be reported by the circuit monitor:

1) Frequency
2) Temperature
3) Current, per phase rms
4) Current, 3-phase average rms
5) Current, apparent rms
6) Voltage, phase-to-phase & phase-to-neutral
7) Power factor, per phase
8) Power factor, 3-phase total
9) Real power, 3-phase total
10) Reactive power, 3-phase total
11) Apparent power, 3-phase total
12) Total Harmonic Distortion

g. The following demand readings shall be reported by the circuit monitor:

1) Average demand current, per phase
2) Peak demand current, per phase
3) Average demand, real power
4) Predicted demand, real power
5) Peak demand, real power

h. The following energy readings shall be reported by the circuit monitor:

1) Accumulated energy
2) Accumulated reactive energy

3. Waveform Capture Capability

a. All electronic circuit monitors shall include waveform capture capability.

b. Upon a user-initiated command, the circuit monitor shall capture and store, in nonvolatile memory, 3-phase voltage and current samples consisting of 256 data points each.

c. These data points shall represent at least four cycles of each current or voltage waveform.

d. These samples shall be evenly gathered from three voltage and three current phases such that the original power signals with proper magnitude and phase relationships may be reconstructed.

e. It shall be possible to recreate the original power signal from the stored data with sufficient accuracy such that steady-state power harmonic analysis will provide valid information on harmonic content for up to the 30th harmonic of the fundamental power frequency.

4. Connecting and Networking Circuit Monitors

a. All data and calculated values stored in the circuit monitor shall be accessible to external devices by means of an RS485/RS422 serial communications port built into the circuit monitor.

b. It shall be possible to connect from one communications port to another such that up to 16 electronic circuit monitors may be connected to form a continuous string extending up to 10,000 feet.

c. These strings shall form individual data transfer networks that comply with the RS485 multi-drop communications standards.

d. Communication rates on this network shall be adjustable up to 19.2 Kbaud to ensure acceptable throughput of data.

e. It shall be possible to connect up to 100 of these networks together by means of network interface modules to form a high speed power monitoring, data acquisition and control network.

5. System Display

a. The circuit monitor shall include an LED readout which will allow local display of the following electrical parameters:

1) Current, per phase rms
2) Voltage, phase-to-phase & phase-to-neutral
3) Real power, 3-phase total
4) Reactive power, 3-phase total
5) Apparent power, 3-phase total
6) Power factor, 3-phase total & per phase
7) Frequency
8) Peak demand current, per phase
9) Peak demand, real power
10) Accumulated Energy, (MWH and MVARH)

b. Reset of the following electrical parameters shall also be allowed from the front of the circuit monitor:

1) Peak demand current
2) Peak demand power
3) Energy (MWH)
4) Reactive energy (MVARH)

c. Circuit monitor setup for system requirements shall be allowed from the front of the circuit monitor. Setup provisions shall include:

1) CT rating (xxxx:5)
2) PT rating (xxxx:120)
3) System type (3-wire and 4-wire)
4) Demand interval (5-60 min.)

d. All reset and setup functions shall be keyswitch-protected to prevent unauthorized/accidental changes.

e. System display units shall be installed by the manufacturer in the equipment as indicated on the drawings.

f. The system display units shall be flush mounted on door panels.

g. The system display unit shall utilize a 4-line by 20-character, high contrast LCD technology display with backlighting to provide high reliability and superior readability in all light conditions.

2.03 INDIVIDUALLY MOUNTED MOTOR CONTROL DEVICES (480, 240, OR 120 VOLT)

A. General

1. All motor control equipment shall be new and the product of 1 manufacturer. All individually mounted disconnects, push-button stations, latchout stations, starters, etc., indoors shall be mounted on a 1 inch galvanized unistrut, 1 inch Kindorf channel, or equal to provide an air space at rear. Outside mounted equipment shall utilize 1-inch 316 stainless steel strut as required in 16070.

B. Starters

1. General

a. All starters shall be of the voltage rating, type, and sized for the motor size shown in these Specifications and/or on the Contract Drawings. For enclosure type see the system operation description and/or the Contract Drawings. All starters shall be of the magnetic type. Should a piece of electrically driven equipment be furnished with a larger motor than shown on the Contract Drawings, the proper size combination starter shall be provided for the equipment supplied, at no extra cost to the Owner.

b. See the Contract Drawings for the auxiliary equipment to be furnished and/or Section 16900 - Controls of this division. **Maximum control voltage shall be 120 volts, a-c.** Minimum starter size shall be NEMA Size 1.

2. Overloads

Each starter shall have an Allen Bradley E300 (or equal) thermal overload device with Ethernet and ground fault protection. The overload shall be a multi-function solid state microprocessor based electronic overload relay for protection of motors. All overloads shall have manual reset and shall be reset without opening the starter enclosure. Relay will be sized for the proper temperature rise of the motor that it is being used on. All integral horsepower motors, 15 horsepower and over, require thermal elements embedded in the windings. See Motor Specifications, this division.

3. Contactors

a. All contactors for motor starters shall be of the a-c magnetic type with “undervoltage” protection when used in conjunction with momentary contact push-button control and “undervoltage” release when used with maintained contact push-button control.

b. Contactor size shall be in accordance with NEMA Standards for the motor controlled and shall be horsepower rated. IEC rated equipment is not acceptable and shall be used as a basis for rejection of the equipment.

c. Contacts shall be of the heavy duty silver-to-silver type and shall be totally enclosed in individual arc quenching chambers. Contacts shall be easily accessible for replacement.

d. The contactor coil shall be of the vacuum impregnated or epoxy resin type, moisture resistant and corrosion proof.

C. Control Stations

1. General

a. Control stations shall be heavy duty, maintained or momentary contact type, as noted on the Contract Drawings. Contacts shall be silver alloy, double break type. The number and marking of controls shall be as shown on the Contract Drawings. Enclosures shall be NEMA 4X for indoor and outdoor mounting, unless otherwise noted on the Contract Drawings. All control stations shall operate on 120 volt, a-c maximum, unless otherwise designated on the Contract Drawings. “Latch-out”

facilities shall be provided where called for in these Specifications and/or on the Contract Drawings.

2. Maintained Contact

   a. Maintained contact control switches shall be marked “On” and “Off”. The button pushed shall remain in and push the other button out until the other button is pushed. In general, they are to be used for hand control of motors which have to operate continuously and restart whenever power is off then resumed, without any manual operator. This is needed for motors which have to operate continuously in the absence of an operator.

3. Momentary Contact

   a. Momentary contact control push-button switches shall be marked “start” and “stop”. Pushbuttons shall spring out whenever pushed. If the circuit is dropped for any reason, operation cannot be resumed until a “start” push-button is pushed. In general, they are to be used for hand control of motors which are desired to operate intermittently in the presence of the operator and stop and start independently from more than one parallel control location.

D. Circuit Breakers

1. Circuit breakers shall be molded case type. Trip elements of multi-pole breakers shall be effectively insulated from one another. Multi-pole breakers shall be designed so that an overload on any one pole shall open all poles simultaneously.

2. The breaker operating mechanism shall be the quick-make, quick-break type and shall be entirely trip free to prevent the contacts being held in a closed position against a short circuit.

3. Breakers not used with motor starters shall be of the thermal magnetic type with a thermal bimetallic element for time delayed overload protection and a magnetic element for short circuit protection.

4. The breaker shall be trip indicating with the trip position midway between the “On” and “Off” positions.

5. Breakers for combination starters shall be 100 amp frame or larger. All breakers for combination starters shall have an adjustable magnetic trip element of the motor circuit protector type.

6. Breakers for combination starters shall be F frame or larger. All breakers shall have adjustable magnetic trip elements. Circuit breakers K frame and larger shall have interchangeable thermal-magnetic trip elements.

E. Safety Switches

1. Safety switches shall be of the heavy duty industrial, quick make, quick-break type. Ratings shall correspond to that of the equipment in which circuit it is used, fuses sized as shown on the Contract Drawings. All safety switches at motor locations are of the nonfused type unless otherwise noted.

2. Safety switches shall have a mechanical door interlock to prevent the door from being opened with the switch in the on position and facilities for locking it in the closed or open position. Enclosures for process areas and outside installations shall be NEMA 4X and enclosures for indoor, non-process areas, shall be NEMA 1, unless otherwise designated in Section 16900 of this division and/or on the Contract Drawings.

3. Safety switches shall be UL listed and shall conform to NEMA Standards. NEMA 4X enclosed safety switches where called for shall be stainless steel, or fiberglass.

4. NEMA 1 enclosed switches shall be phosphate coated or equivalent, code gauge steel with baked enamel finish.

F. Selector Switches

1. Hand-off-automatic type selector switches shall be of oil-tight construction and shall have 3 positions. The switch must not have a spring loaded return. It shall be of the "quick-make", "quick-break" type.

G. Manual Motor Starting Switches

1. Manual motor starting switches for the control of fractional horsepower motors shall be single pole, and shall be provided with a thermal heater of the correct size for the load controlled. Each starting switch shall be mounted where shown on the Contract Drawings. Where they are used for rotating equipment such as grinders, they shall be equipped with low voltage protection, and required manual reset after power failure. As an alternate to low voltage protection built-in, a "Safety Restart Plug" may be utilized, available from Mitchell Instrument Company.

H. Alarm Horns

1. Alarm horns, where called for on the Contract Drawings, shall be weatherproof, suitable for surface mounting and shall be provided with a silence button. Alarm horn shall be Edwards 876 series with 103dB at 10 feet, Federal Signal, or equal.

I. Timing Relays

1. Time delay relays shall have an adjustable timing range as shown on the Contract Drawings. The time delay shall be after energizing timer coil. Timing relays shall be Agastat, Square D, or equal.

2.04 TIMERS

A. Timers for various services required in the motor control equipment shall be Paragon, Tork or equal as indicated in control circuits shown on the Drawings.

B. Timers requiring tripping pins shall be supplied with enough pins to completely fill all locations on the dial face.

2.05 REDUCED VOLTAGE SOLID STATE STARTER

A. The solid-state reduced-voltage starter shall be UL and CSA listed. The solid-state reduced-voltage starter shall be an integrated unit with power SCRs, logic board, an integral paralleling bypass contactor, and electronic overload relay enclosed in a single molded housing. The starter shall meet all applicable requirements of this Section and other sections in this Division.

B. The RVSS shall be suitable for continuous operation at 115% of its continuous ampere rating. To ensure that pump or blower/motor load starting torque requirements are met, the Contractor shall furnish the starter of the next higher maximum continuous current rating than otherwise required based on the full load ampere rating of the motor.

The Contractor is fully responsible for the review of the mechanical specifications to determine specified motor speed, horsepower and full load amperes. This information is available in the applicable mechanical specifications for each piece of equipment (e.g. backwash blower).

C. The RVSS shall be suitable for the following environmental conditions:

Operating Temperature: 0-50 degrees C
Humidity: 0-95 percent non-condensing.
Altitude: up to 3,300 feet.

D. The RVSS shall be suitable for operation on a 480 VAC, 3-phase, 60 Hertz system.

E. The SCR-based power section shall consist of six (6) back-to-back SCRs and shall be rated for a minimum peak inverse voltage rating of 1500 volts PIV. Units using triacs or SCR/diode combinations are not acceptable. Resistor/capacitor snubber networks shall be used to prevent false firing of SCRs due to dv/dt effects.

F. The integral paralleling run bypass contactor shall energize when the motor reaches full speed and close/open under one (1) times motor current. The paralleling run bypass contactor shall utilize an intelligent coil controller to limit contact bounce and optimize coil voltage during varying system conditions. The coil shall have a lifetime warranty.

G. The starter shall be provided with electronic overload protection as standard and shall be based on an inverse time-current algorithm. Overload protection shall be capable of being disabled during ramp start for long acceleration loads via a DIP switch setting on the device keypad. Overload protection shall be adjusted via the device keypad and shall have a motor full load ampere adjustment from 30 to 100% of the maximum continuous ampere rating of the starter. The starter shall have selectable overload class setting of 5, 10, 20 or 30 via a DIP switch setting on the device keypad. The starter shall be capable of either an electronic or mechanical reset after a fault. Units using bimetal or eutectic alloy overload relays are not acceptable. Overtemperature protection (on heat sink) shall be standard.

H. The starter shall provide protection against improper line-side phase rotation as standard. The starter shall stop the motor load if a line-side phase rotation other than A-B-C exists. This feature may be disabled via a DIP switch on the device keypad.

I. The starter shall provide protection against a phase loss or unbalance condition as standard. The starter shall stop the motor load if a 50% current differential between any two phases is encountered. This feature may be disabled via a DIP switch on the device keypad.

J. The starter shall provide protection against a motor stall condition as standard. This feature may be disabled via a DIP switch on the device keypad.

K. The starter shall provide protection against a motor jam condition as standard. This feature may be disabled via a DIP switch on the device keypad.

L. The starter shall be provided with a form C normally open (NO), normally closed (NC) contact that shall change state when a fault condition exists. The contacts shall be rated 60 VA (resistive load) and 20 VA (inductive load). In addition, an LED display on the device keypad shall indicate the type of fault (Overtemp, Phase Loss, Jam, Stall, Phase Reversal, and Overload).

M. The starter shall be provided with an unpowered internal “Run” contact rated for 24VDC or 120 VAC operation.

N. The following control function adjustments on the device keypad shall be provided:

1. Selectable Torque Ramp Start or Current Limit Start

2. Adjustable Kick Start Time, 0-2 seconds

3. Adjustable Kick Start torque, 0-90%

4. Adjustable Ramp Start Time; 0.5-180 seconds

5. Adjustable Initial Starting Ramp Torque; 0-100%

6. Adjustable Smooth Stop Ramp Time; 0-60 seconds.

The Human Interface Module (HIM) provided for the RVSS shall be the same as provided for the variable frequency drives.

O. Enclosed units shall include a thermal-magnetic circuit breaker for short-circuit protection and quick disconnect means. If required, the unit shall include a 24 VDC power supply to be used as the primary control voltage source. A 120 VAC control power transformer, fused on both the primary and secondary sides, shall be provided as an additional control power source to power such devices as motor space heaters, solenoid valves, and similar control elements as required. Input and output isolation contactors shall be furnished as indicated on the Drawings.

P. Unless otherwise specified or indicated on the Drawings, the RVSS enclosure shall be NEMA 1A (gasketed), force ventilated, dead-front, with front accessibility. The enclosure shall be designed for both bottom and top entry. The enclosure shall be designed so rear access is not required for operations, maintenance, and repair tasks. The doors shall have full length piano type hinges and shall be braced to prevent sag when fully open. Other enclosure requirements are:

1. Treat metal surfaces and structural parts by phosphatizing prior to painting.

2. Apply a gun-metal gray undercoat to enclosures which is equal to zinc chromate.

3. Finish exterior of the enclosures in ANSI-61 gray enamel or furnish in a color to match the complete line-up of equipment as indicated on the Drawings and accepted by the Engineer.

Q. The complete starter assembly shall be rated per UL 508D for a minimum withstand rating of 65 kAIC rms. Starters enclosed in motor control centers shall be by the same manufacturer.

R. The following accessories and spare parts shall be provided for each starter:

1. Surge suppressor mounted on the line side of the starter to clip the input line voltage.

2. Lug kits for both the line and load side of the starter.

3. One (1) user's manual for each frame size of starter.

4. One (1) spare 24VDC power supply for each size used.

S. The reduced voltage solid state starter shall be the SMC-Flex with integral bypass as manufactured by Allen-Bradley, Cutler-Hammer equivalent, the General Electric Company equivalent, the Square D Company equivalent, or Siemens Energy and Automation, Inc. equivalent.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Motor Control Centers

1. Ends of MCC(s) shall be closed with 1/4" mesh hardware cloth and galvanized or aluminized insect screen or sill covers to prevent the entrance of rodents and large insects into the MCC housing(s).

2. Each MCC shall be provided with a 4" high concrete pad.

3. One inch air space (min.) shall be allowed between back of MCC(s) and wall surface.

4. Lifting-eyes in tops of MCC(s) section shall be removed (and retained) and the threaded openings closed with stainless cap screws and plastic washers or plastic seals provided for that purpose by the MCC(s) manufacturer.

5. In installations where conduit runs to electrical equipment emanate from the top of MCC(s) there shall be provided additional wiring space in the form of metal trough(s) of the same metal housing(s) dimensions and details. Trough(s) shall be provided by the manufacturer of the MCC(s).

B. Individually Mounted Motor Control Devices (480, 240, or 120 Volt)

1. Each motor disconnect shall be located as near as possible to its respective motor.

2. Remote control station at or near motor shall be mounted near its respective motor, adjacent to the motor disconnect.

3. All devices and equipment furnished under this section (electronic circuit monitors, power correction equipment, etc.) shall be programmed, configured, and calibrated by the manufacturer. Any settings required shall be as determined by the manufacturer. If coordination studies or power system analysis is required, it shall be performed by the manufacturer.

3.02 EXTRA STOCK/SPARE PARTS

A. Provide the following spare parts:

10	fuses of each type/amperage used
1	pilot light lamp for each pilot light socket assembly provided
1	control transformer for each size utilized

END OF SECTION

SECTION 16442 - PANELBOARDS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. This section of the Technical Specifications includes furnishing all labor, materials, equipment, and incidentals required for the installation of all lighting and distribution panelboards as hereinafter specified and as shown on the Contract Drawings.

B. The panelboards for installation under this Contract shall be selected from the following types with the panel voltage and main sizes the determining factors. All panelboards shall be by the same manufacturer.

C. Circuit breakers of size and type shown on Contract Drawings and described herein shall be provided with the panelboards.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Square D”, “Cutler Hammer”, “General Electric Company,,”, “ABB” or equal.

2.02 EQUIPMENT

A. Rating

1. Panelboard ratings shall be as shown on the Contract Drawings. All panelboards shall be rated for the intended voltage.

B. Standards

1. Panelboards shall be in accordance with the Underwriter Laboratories, Inc. “Standard for Panelboards” and “Standard for Cabinets and Boxes” and shall be so labeled where procedures exist. Panelboards shall also comply with NEMA Standard for Panelboards and the National Electrical Code.

C. Panelboard Construction (NEMA 1)

1. Interiors

a. All interiors shall be completely factory assembled with circuit breakers, wire connectors, etc. All wire connectors, except screw terminals, shall be of the anti-turn solderless type and all shall be suitable for copper or aluminum wire of the sizes indicated.

b. Interiors shall be so designed that circuit breakers can be replaced without disturbing adjacent units and without removing the main bus connectors and shall be so designed that circuits may be changed without machining, drilling or tapping.

c. Branch circuits shall be arranged using double row construction except when narrow column panels are indicated. Branch circuits shall be numbered by the manufacturer.

d. A nameplate shall be provided listing panel type, number of circuit-breakers and ratings.

2. Bussing

    a. Bus-bars for the mains shall be of copper. Full size neutral bars shall be included. Bus-bar taps for panels with single pole branches shall be arranged for sequence phasing of the branch circuit devices. Bussing shall be braced throughout to conform to industry standard practice governing short circuit stresses in panelboards. Phase bussing shall be full height without reduction. Cross connectors shall be copper.

    b. Neutral bussing shall have a suitable lug for each outgoing feeder requiring a neutral connection.

    c. Spaces for future circuit-breakers shall be bussed for the maximum device that can be fitted into them.

    d. Separate neutral and ground bus shall be provided, insulated and isolated from each other.

3. Boxes

    a. Recessed boxes shall be made from galvanized code gauge steel having multiple knockouts, unless otherwise noted. Surface mounted boxes shall be painted to match the trim. Boxes shall be of sufficient size to provide a minimum gutter space of 4 inches on all sides.

    b. Surface mounted boxes shall have an internal and external finish as hereinafter specified. Surface mounted boxes shall be field punched for conduit entrances.

    c. At least 4 interior mounting studs shall be provided.

4. Trims

    a. Hinged doors covering all circuit-breaker handles shall be included in all panel trims.

    b. Doors shall have semi flush type cylinder lock and catch, except that doors over 43 inches in height shall have a vault handle and 3-point catch, complete with lock, arranged to fasten door at top, bottom and center. Door hinges shall be concealed. Two keys shall be supplied for each lock. All locks shall be keyed alike; directory frame and card having a transparent cover shall be furnished on each door.

    c. The trims shall be fabricated from code gauge sheet steel.

    d. All exterior and interior steel surfaces of the panelboard shall be properly cleaned and finished with manufacturer's standard gray paint over a rust-inhibiting phosphatized coating. The finish paint shall be of a type to which field applied paint will adhere without cracking or peeling.

    e. Trims for flush panels shall overlap the box by at least 3/4 inch all around. Surface trims shall have the same width and height as the box. Trims shall be fastened with quarter turn clamps.

D. Overcurrent Protective Devices (Circuit Breakers)

1. Panelboards shall be equipped with circuit-breakers with frame size and trip settings as shown on the Contract Drawings.

2. Circuit-breakers shall be molded case, bolt-in, thermal-magnetic trip.

3. Circuit-breakers used in 120/208 volt panelboards shall have an interrupting capacity of not less than 10,000 amperes, RMS symmetrical.

4. Circuit-breakers used in 480 volt panelboards shall have an interrupting capacity of not less than 22,000 amperes, RMS symmetrical.

5. GFCI (ground fault circuit interrupter) shall be provided for circuits where indicated on the Contract Drawings. GFCI units shall be 1-pole, 120 volt, molded case, bolt-on circuit-breakers, incorporating a solid state ground fault interrupter circuit insulated and isolated from the circuit-breaker mechanism. The unit shall be UL listed Class A Group I device (5 milliamp sensitivity, 25 millisecond trip time), and an interrupting capacity of 10,000 amperes RMS.

6. Trip elements of multi-pole breakers shall be effectively insulated from one another. Multi-pole breakers shall be designed so that an overload on any pole shall open all poles simultaneously.

7. The breaker operating mechanism shall be the quick-make, quick-break type and shall be entirely trip free to prevent the contacts being held in a closed position against a short circuit.

8. Breakers shall have a thermal bimetallic element for time delayed overload protection and a magnetic element for short circuit protection.

9. The breaker shall be trip indicating with the trip position midway between the “On” and “Off” positions.

10. Breakers for power distribution panels shall be F frame or larger. All breakers rated above 225 amps shall have interchangeable magnetic trip elements.

11. All breakers shall be UL listed, and conform to requirements of NEMA Standards.

E. Surge Protective Devices

1. See Section 16280 – Surge Protection Devices for panelboard SPD requirements.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. Boxes for surface mounted panelboards shall be mounted so there is at least 1/2 inch air space between the box and the mounting surface.

B. Circuit directories shall be typed giving location and nature of load served.

C. Each panelboard shall be nameplated with plastic engraved nameplates stating the panel’s name, voltage, and the name of panel serving the panel. Nameplates shall be secured by use of stainless steel screws.

END OF SECTION

SECTION 16445 - MEDIUM VOLTAGE VARIABLE FREQUENCY MOTOR CONTROLLERS

PART 1 - GENERAL

1.01 SUMMARY

A. Scope: Provide labor, material, equipment, related services, and supervision required, including, but not limited to, manufacturing, fabrication, erection, and installation for medium voltage variable frequency motor controllers (also identified as MV VFDs, MV AFDs, or MV Adjustable Frequency Drives) as required for the complete performance of the work, and as shown on the Drawings and as herein specified.

B. Section Includes: The work specified in this Section includes, but shall not be limited to, the following:

1. The design, construction, performance, inspection, testing, shipment, and documentation of 4160 volt AC, three-phase input, MV VFDs supplying squirrel cage induction motors. The scope of this specification defines the application for indoor, non-classified areas and shall result in a long design life with very low maintenance requirements.

C. Related Sections: Related sections include, but shall not be limited to, the following:

1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

2. Applicable general requirements for electrical Work specified within Division 16 Specification Sections apply to this Section.

3. Refer to the specifications sections for the MV VFD driven equipment for additional requirements

1.02 REFERENCES

A. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by the basic designation only. The edition/revision of the referenced publications shall be the latest date as of the date of the Contract Documents, unless otherwise specified.

1. Canadian Standards Association (CSA):

a. CSA C22.2 No. 14, “Industrial Control Equipment.”

2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

a. ANSI/IEEE 519, “Guide for Harmonic Control and Reactive Compensation of Static Power Converters”

b. ANSI/IEEE C57.18.10, “Standard Practices and Requirements for Semiconductor Power Rectifier Transformers”

c. ANSI/IEEE C57.110, “Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsine wave Load Currents”

3. International Electrotechnical Commission (IEC):

a. IEC 60076, “Power Transformers”

b. IEC 61131-3 “”Programmable controllers Part 3: Programming languages”

c. IEC 60146, “Semiconductor Converters - General Requirements and Line Commutated Converters”

d. IEC 60726, “Dry Type Power Transformers”

e. IEC 61378-1,”Converter Transformers - Part 1: Transformers for Industrial Applications”

f. IEC 61800-3, “Adjustable Speed Electrical Power Drive Systems - Part 3: EMC Requirements and Specific Test Methods”

g. IEC 61800-4, “Adjustable Speed Electrical Power Drive Systems - Part 4: General Requirements - Rating Specifications for AC Power Drive Systems Above 1000 Volts AC and not Exceeding 35 kV”

h. IEC 61800-5, “Adjustable Speed Electrical Power Drive Systems - Part 5: Safety Requirements”

4. International Organization for Standardization (ISO):

a. ISO 9001, “Quality Management Systems - Requirements”

5. Underwriters Laboratories, Inc. (UL):

a. UL 347, “Medium Voltage AC Contactors, Controllers, and Control Centers”

1.03 DEFINITIONS

A. Unless specifically defined within the Contract Documents, the words or acronyms contained within this specification shall be as defined within, or by the references listed within this specification, the Contract Documents, or, if not listed by either, by common industry practice.

1. MV: Medium voltage
2. LV: Low voltage
3. VFD: Variable frequency drive
4. VSI: Voltage source inverter
5. AFE: Active front end
6. DFE: Diode front end
7. MTBF: Mean time between failure
8. MTTR: Mean time to repair
9. NPC: Neutral point clamped
10. IGBT: Insulated gate bipolar transistor
11. PWM: Pulse width modulation
12. SUBMITTALS

B. General: Submittals shall be in accordance with the requirements of Section 01300 Submittals and Division 16 Electrical, in addition to those specified herein.

1. Submit sufficient information to determine compliance with the Contract Documents. Identify submittal data with the specific equipment tags and/or service descriptions to which they pertain. Submittal data shall be clearly marked to identify the specific model numbers, options, and features of equipment and work proposed.

2. Deviations from the Contract Documents shall be indicated within the submittal. Each deviation shall reference the corresponding drawing or specification

number, show the Contract Document requirement text and/or illustration, and shall be accompanied by a detailed written justification for the deviation.

C. Product Data: Submit product data specific to each type and rating of MV VFD proposed to include the following:

1. Manufacturer, supplier, and proposal specific contact information
2. Manufacturer's catalog data indicating model numbers, equipment specifications and construction features including all furnished options, and accessories
3. MV VFD assembly rated input KVA and output KVA, topology, converter/inverter type, percent efficiency, operating characteristics, and electrical characteristics
4. Maximum Btu heat release data and ambient cooling requirements
5. Enclosure type, NEMA rating, material and finishes
6. Certification of UL conformity

D. Shop Drawings: Submit shop drawings for each product and accessory required. Include information not fully detailed in manufacturer’s standard product data. Shop drawings shall include, but shall not be limited to, the following: Electronic 2D dimensional drawing for standard units shall be provided.

1. Equipment assembly. Indicate dimensions, shipping section dimensions, weights, foundation requirements, required clearances, location and size of each field connection, and mounting and installation instructions.
2. Include elementary and interconnection diagrams for power, signal, control, and communications wiring. Diagrams shall provide the minimum detail as shown for drawings in the appendix of NFPA 79. All field terminals shall be identified and updated later within the O&M data to include actual field connection information. Drawings shall not be typical, but be provided for each MV VFD furnished.

E. Wiring Diagrams: Submit wiring diagrams detailing power, signal, and control systems, clearly differentiating between manufacturer-installed wiring and field-installed wiring, and between components provided by the manufacturer and those provided by others.

F. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Required working clearances and required area above and around MV VFDs
2. Show MV VFD layout and relationships between electrical components and adjacent structural and mechanical elements
3. Show support locations, type of support, and weight on each support
4. Indicate field measurements

G. Harmonic Analysis Report: Provide project-specific calculations and manufacturer's statement of compliance with IEEE 519, latest revision. Owner shall supply detailed electrical power system characteristics to support harmonic calculations.

H. Operation & Maintenance (O&M) Manuals: Submit installation, operation, and maintenance data to be included within operation and maintenance manuals. In addition to items specified in Section 1780 "Operation and Maintenance Manuals.” O&M data shall include but not be limited to the following:

1. Manufacturer, supplier, support, and repair center specific contact information.
2. Manufacturer’s standard operation and maintenance data assembled for each size and type of equipment furnished.

3. All construction, installation, schematic, and wiring diagrams updated to an as-installed and commissioned state. All configured settings/parameters for adjustable components updated to an as-installed and commissioned stated if different from the factory default. Electronic copies of configuration files shall be provided, on media acceptable to the Owner (e.g. CD, USB stick, etc.), where these configurations can be saved as an electronic file for future upload into replaced or repaired components.

4. List of furnished and recommended spare parts.

5. Statement of standard Warranty. Statement of extended warranty options and costs.

I. O&M manuals shall be submitted prior to arrival of equipment on site.

1.04 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturer Qualifications: Manufacturer shall be a firm engaged in the manufacture of variable frequency motor controllers of types and sizes required, and whose products have been in satisfactory use in similar service for a minimum of ten years.

   a. The manufacturer shall have a valid ISO 9001 certification and an applicable quality assurance system that is regularly reviewed and audited by a third party registrar. Manufacturing, inspection, and testing procedures shall be developed and controlled under the guidelines of the quality assurance system.

   b. The manufacturer or their representative shall have service, repair, and technical support services available 24 hours 7 days a week basis.

   c. The manufacturer shall be offer a wide range of horse power ratings and voltages utilizing validated topologies.

   d. The manufacturer shall offer a full complement of options to meet the project requirements. Available options shall include, but shall not be limited to the following: multi-motor/redundant drive configurations, dynamic braking chopper, input filters, output filters, output isolation switch, motor grounding switch, cooling fan motor circuit, redundant cooling fan(s), ability for air extraction by duct, communication modules for standard protocols, custom panel meters and operator controls, marine construction, top cable entry, and custom color painting.

2. Installer Qualifications: Installer shall be a firm that shall have a minimum of ten years of successful installation experience with projects utilizing variable frequency motor controllers similar in type and scope to that required for this Project.

3. Startup and Training: MV VFDs shall be inspected, configured, and tested by a factory trained representative of the MV VFD manufacturer. MV VFD operation and maintenance training shall be conducted by a factory trained representative of the MV VFD manufacturer trained in the installation, operation, and maintenance of the MV VFD.

B. Regulatory Requirements: Comply with applicable requirements of the laws, codes, ordinances, and regulations of Federal, State, and local authorities having jurisdiction. Obtain necessary approvals from such authorities.

1. Without limiting the generality of other requirements of this Section, all work specified herein shall conform to or exceed the applicable requirements of the following standards; provided, that wherever the provisions of said publications

are in conflict with the requirements specified herein, the more stringent requirements shall apply:

a. CSA C22.2 No 14

b. ANSI/IEEE 519

c. ANSI/IEEE C57.18.10 and ANSI/IEEE C57.110 (if a transformer is required)

d. IEC 60146

e. IEC 61800-3, IEC 61800-4, and IEC 61800-5

f. IEC 60076, IEC 60726, and IEC 61378-1

g. UL 347

C. Pre-Installation Conference: Prior to commencing the installation, meet at the Project site to review the material selections, installation procedures, and coordination with other trades. Pre-installation conference shall include, but shall not be limited to, the Contractor, the Installer, manufacturer's representatives, and any trade that requires coordination with the work. Date and time of the pre-installation conference shall be acceptable to the Owner and the Architect.

D. Single Source Responsibility: Obtain medium voltage variable frequency motor controllers and required accessories from a single source with resources to produce products of consistent quality in appearance and physical properties without delaying the work. Any materials which are not produced by the manufacturer shall be acceptable to and approved by the manufacturer or their representative.

E. All MV VFDs shall be functionally tested by the manufacturer. A test report shall be submitted to Owner and Engineer.

1.05 SPECIAL TOOLS AND SPARE PARTS

A. The Contractor shall provide a recommended spare parts list with the following information provided as a minimum:

1. Contact information for the closest parts stocking location to the Owner.

2. Critical spare parts shall be identified as those parts being associated with long lead times and/or those being critical to the unit's operation.

3. Maintenance spares shall be identified as being those parts required to regularly perform scheduled maintenance on the MV VFD equipment. These spares shall include, but shall not be limited to, consumable spares that are required to be exchanged during scheduled maintenance periods.

B. Spare parts shall be provided for each type and size of MV VFD furnished. Provide at least one complete set of all plug-in replaceable components of each size and type used. At a minimum the following shall be provided:

1. Power and control fuses (6 of each type)

2. Non-LED type indicating lights (2 of each type)

3. Rectifier power semiconductors or rectifier module

4. Inverter power semiconductors or basic power module

5. One of each type of printed circuit board and gate firing board

6. Other field replaceable components (e.g. fan)

C. Any manufacturer specific special tool, not normally found in an electrician's toolbox, required to remove and install recommended or furnished spare parts shall be furnished. At a minimum the following shall be provided:

1. PC-based configuration software tool

2. Electronic configuration files, in a media format acceptable by the Owner (e.g. CD, USB stick, etc.), updated to an as-installed and commissioned state.

D. Spare parts shall be properly marked and packaged for long term storage. Printed circuit boards shall be provided in separate anti-static containers.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Unless specified otherwise, preparation for shipment shall be in accordance with manufacturer's standards for the particular shipping method and end destination.

B. Loose equipment shall be appropriately packaged and secured for shipment inside the enclosure or shipping container. These items shall be properly tagged for easy identification.

C. Prior to delivery to the Project Site, ensure that suitable storage space is available to store materials in a well-ventilated area protected from weather, moisture, soiling, extreme temperatures, humidity, and corrosive atmospheres. Materials shall be protected during delivery and storage and shall not exceed the manufacturer stated storage requirements.

D. Deliver materials to the Project site in supplier's or manufacturer's original wrappings and containers, labeled with supplier's and manufacturer's name, material or product brand name, and lot number, if any.

E. Store materials in their original, undamaged packages and containers, inside a well-ventilated area protected from weather, moisture, soiling, extreme temperatures, and humidity.

F. Equipment shall be handled and stored in accordance with the manufacturer's instructions. One copy of these instructions shall be included in the equipment at the time of shipment.

G. Inspect and report any concealed damage or violation of delivery storage, and handling requirements to the Engineer.

1.07 WARRANTY

A. General: Refer to Section 01782 – Warranties and Bonds.

B. The manufacturer warrants and guarantees that the supplied MV VFDs are not defective and shall provide warranty to include all parts, labor, and travel expenses associated with the repair of any defects for a period of 24 months after the Owner utilizes the equipment or partial/substantial completion has been attained - whichever comes first. This period shall not exceed 30 months from the date of shipment of the MV VFDs. This warranty shall be in addition to any provided by the Contractor. The warranty shall exclude normal wear and tear under normal usage and any damage caused by abuse, modification, or improper maintenance by entities other than the manufacturer or its approved representative.

C. Additional Owner Rights: The warranty shall not deprive the Owner of other rights the Owner may have under other provisions of the Contract Documents and shall be in

addition to and run concurrent with other warranties made by the Contractor under requirements of the Contract Documents.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Basis-of-Design Product: Rockwell Powerflex 6000.

B. Acceptable Products: MV VFDs specified herein shall be the product of a single manufacturer. Products and manufacturers specified are to establish a standard of quality for design, function, materials, and appearance. Products shall be modified as necessary by the manufacturer for compliance with requirements. Provide the following specified product and manufacturer without exception, unless approved as a substitute by addendum to the Contract Documents prior to the bid date:

1. Altivar 1260 by Schneider Electric
2. Equal unit by Robicon
3. Rockwell Powerflex 6000

2.02 SYSTEM REQUIREMENTS

A. MV VFD's shall be a pulse width modulated (PWM) inverter utilizing Insulated Gate Bipolar Transistors (IGBTs) in a cascaded H Bridge design. Components and materials shall be new and of the latest field-proven design and in current production. The use of lower voltage rated output devices is unacceptable due to the reliability of topology and quantity of devices. Obsolete components or components scheduled for immediate discontinuation shall not be used.

B. The MV VFD shall be capable of controlling induction AC motors without the requirement for an inverter duty motor. The MV VFD shall produce a variable voltage and variable frequency output to provide continuous operation and speed control of the motor over speed range of the application.

C. The MV VFD shall utilize vector control strategies with the control of three level rectifiers and inverters based on the latest semiconductor technologies commanded via fiber optics to produce a safe and flexible solution with a user friendly interface.

D. In operation, the rectifier shall provide an intermediate medium voltage DC bus from the main MV AC power supply. Subsequently, the inverter shall supply the motor from the DC bus with the required frequency and voltage values according to the torque and speed settings demanded by the application. Additional features supplied from LV AC power supply (cooling system, DC bus pre-charge and discharge systems, grounding switch, etc.) shall help provide precise and safe operation of the converter. The entire assembly shall be controlled by a parameterized control unit with a human-machine interface. The MV VFD shall be comprised of, but not limited to, the following:

1. Rectifier Transformer
2. Rectifier
3. Inverter
4. Output filter
5. DC bus
6. Control unit
7. Enclosure

E. The MV VFD shall be factory pre-wired, assembled, and tested as a complete package. When it is necessary to disassemble the units for ease of transportation, adequate materials and instructions shall be provided for easy field reassembling where all wiring and interconnections are supplied. Customer specific drive, motor, and application data, if made available to manufacturer prior to or during shop drawing review, shall be pre-loaded into the operator interface and tested prior to shipment.

2.03 PERFORMANCE REQUIREMENTS

A. The MV VFD shall have a normal duty rating of 100% continuous current with a short time duty rating of 115% overload for one minute, once every 10 minutes (suitable for variable torque loads). The MV VFD shall have torque overload capabilities of 110% for one minute and 120% for 10 seconds.

B. The MV VFD shall utilize a supply input voltage within ±10% of the nominal line voltage and shall maintain operation during a voltage sag of 30% for at least 5 cycles. The MV VFD shall have a flying re-start with the capability to synchronize onto a spinning load and develop full acceleration torque within 10 seconds.

C. The MV VFD shall utilize V/Hz, sensorless vector control or full vector control. Vector control shall use pulse tachometer or encoder feedback, for controlled speed over the range specified. Speed accuracy within this range, expressed as a percent of top speed, shall be within 0.1% of base speed without encoder or pulse tachometer feedback (0.01% with encoder or pulse tachometer feedback). Range of speed variation shall be 0% to 100%. Torque accuracy shall be less than 5% of rated torque in sensorless and encoder vector control with less than 6 ms dynamic torque response time.

D. Efficiency: MV VFD system efficiency shall be ≥96% at 100% speed and 100% load. System efficiency shall include, but shall not be limited to, MV VFD, input transformer or line reactor, harmonic filter (if applicable), power factor correction unit (if applicable), and output filter (if applicable). Control power supplies, control circuits, and cooling fans or pumps shall be included in all loss calculations. The efficiency of the MV drive frequency converter (no input filters) shall be ≥97.7% efficiency at 100% speed and ≥97.3 at 50% speed when using an output sine wave filter.

E. Power Factor: The MV VFD input power factor shall be 96% at full load and greater than 95% for rated loads between the speed range of 20% to 100%. The MV VFD shall be able to maintain this power factor without the use of power factor correction capacitors.

F. Line Side Harmonics: The MV VFDs shall comply with the latest edition of ANSI/IEEE 519 harmonic guidelines. Harmonic requirements shall be satisfied with a minimum of 24-pulse rectification, an Active Front End (AFE), or a separately installed Active Harmonic Filter.

G. Environmental:

1. The MV VFD provide shall 100% output current continuously for an ambient temperature range of 32°F (0°C) to 104°F (40°C) with a relative humidity range of 5% to 98% (non-condensing) at altitudes from 0 feet (0 m) to 3281 feet (1000 m) above sea level, without de-rating.

2. The MV VFD shall be able to provide a 100% load current continuously under the specified installation environmental conditions. The manufacturer shall provide the required derating(s) if the ambient temperature is higher than 104°F (40°C) and / or if the installation altitude is more than 3281 feet (1000 m) above the sea level. This shall be clearly identified within the submittals. The derating factor(s) shall not adversely affect the stated lifetime, performance, overload capability, or the reliability of the MV VFD.

3. The equipment shall be capable of being stored in an environment with an ambient temperature range of 5°F (-15°C) to 167°F (75°C).

4. Maximum audible noise from the MV VFD system shall comply with OSHA hearing conservation, which limits noise level to 80 dB(A). The MV VFD system shall comply with the OSHA standard at a distance of 3.28 feet (1 m) from the front of the equipment (with doors closed at any speed or load condition).

H. Motor Compatibility:

1. The MV VFD shall provide near sine wave voltage and current waveforms to the motor at all speeds and loads. An output sine wave filter shall be provided if required integral to the MV VFD controller and shall meet any special requirements of the application including the use of motors that are not converter rated.

2. The MV VFD output voltage shall not cause insulation stress to the motor or exceed the peak voltage insulation level of the motor for cable lengths in lengths up to 300 meters. The output sine wave filter shall limit $V_{(peak)}$ at the motor terminals to ≤6 kV. MV VFD induced torque pulsations to the output shaft of the mechanical system shall be less than 1% to minimize the possibility of exciting a resonance. The output THDi shall be <2% and dV/dt shall be ≤50V per microsecond.

I. Drive Protection: The MV VFD shall include, but not be limited to, the following minimum protection features:

a. Instantaneous overcurrent
b. Instantaneous overvoltage
c. Inverter status
d. Under voltage
e. Input phase loss
f. Output phase loss
g. Power loss
h. Over temperature
i. Under temperature
j. Overload
k. Motor stalled
l. Motor over temperature
m. Motor under load
n. Microprocessor status
o. Logic voltage status
p. Ground fault
q. Communication error

J. Reliability:

1. The MV VFD system shall be designed for a minimum availability of 99.7%.

2. The MV VFD system shall be designed for a mean time between failures (MTBF) not less than 75,000 hours.

3. The MV VFD system shall be designed for a minimum life expectancy not less than 15 years.

4. In order to optimize reliability and minimize complexity, inverter power switch component count shall be minimized by utilizing high peak inverse voltage (PIV) rated devices. Preference shall be given to designs exhibiting the lowest overall power component count.

2.04 DESIGN AND FABRICATION

A. Modular design shall allow a wide range of powers and voltages utilizing intuitive structures which shall enhance and make it easier to use and maintain the converter as well as diagnose and trouble shoot system operations.

B. Metal or plastic barriers shall be provided between each vertical section and between the low voltage compartment and the power cell. Personnel shall have controlled access to the low voltage compartment with the MV VFD energized without being exposed to any voltage exceeding 480 volts AC.

C. Tin-plated power and ground copper bus bars shall be used.

D. Conformally coated circuit boards shall be provided to minimize potentially dangerous conductive dust short circuits. Gloves shall not be required for equipment protection when handling drive components during maintenance and repair.

E. A single external power source of 480 volt, three-phase 50/60 hertz shall be provided to the VFD for conversion and distribution of auxiliary power within and integral to the VFD. Control power shall be provided by a single-phase transformer (CPT) integrated internally to the VFD. The CPT primary shall be fused and shall have one terminal grounded. CPT rating shall be determined by the manufacturer and shall have a minimum 25 percent spare capacity. VFDs that require external control power are not acceptable

F. A main horizontal power bus shall be located in the VFD, at the back of the structure, to provide optimum heat distribution, ease of maintenance and splicing. The power bus shall be mounted on edge to a molded bus support insulator in a common vertical plane. The power bus shall be made of tin-plated copper and rated to meet design requirements. Access shall be provided to the bus compartment from the front of the structure to allow for installation and regular maintenance of the power and ground bus splice connections.

G. The horizontal buswork and the cabling/bus from the main power cell shall be braced in accordance with NEMA ICS 3-2005 (R2010) and UL 347. The buswork and cabling shall be braced to withstand the let-through energy of the largest fuse during a short circuit event.

H. DC bus capacitor charging shall be accomplished by use of a DC bus pre-charge circuit. The DC bus capacitors shall be charged before application of main power, which shall limit the inrush currents to the main rectifier/converter bridge devices. When the proper DC bus voltage is attained, the pre-charge circuit shall turn off.

I. A voltage limiting chopper shall be supplied to reduce the potential of a DC bus overvoltage when the application returns energy to the converter. The device shall be capable of containing the DC bus capacitors and maintaining it at normal operating values to reduce the chance of device damage.

J. A continuous copper ground bus shall be provided along the entire length of the controller line-up. A mechanical lug for #8 to #1/0 AWG or #6 to 250 MCM cable shall be supplied at the incoming end of the line-up. The ground bus shall be ¼ inch (6 mm) by 2 inches (51 mm) bare copper.

K. Each VFD shall include, but shall not be limited to a fused manually operated input/output isolation switch with visible blades, and a removable vacuum contactor to feed the isolation/phase shifting transformer. This shall be provided to safely isolate the drive from the power source.

L. MV VFD Drives shall form a rigid self-supporting structure suitable for floor mounting and for installation in an indoor unclassified area. The enclosure shall be air-cooled and rated NEMA 1 with forced ventilation and filters. Safety screens shall be located behind each louver panel.

M. Cabinets and doors shall be fabricated using a minimum 16 gauge (1.5 mm) thick steel. Doors shall be gasketed to provide environmental protection and secure fits. Door latches shall be heavy duty type units. Hinged doors containing electrical components shall be grounded using a separate strap.

N. The MV VFD shall be designed for front access to all components. Components (i.e., rectifiers, inverters, etc.) shall be constructed so service or replacement can be done from the front and by no more than two people. Equipment that requires rear or side access will not be accepted.

O. The MV VFD shall be designed in such a way as to provide a MTTR of less than 30 minutes for at least the control modules, basic power stack modules (MV-IGBTs and diodes), and fuses. Any components exceeding this limit shall be clearly identified within the submittals.

P. The converter cabinet door and cabling cabinet door shall be interlocked with up-stream isolators or breakers with a key lock. Interlocking shall be fully coordinated to prevent access to medium voltage compartments. The MV VFD shall have an auxiliary enclosure on the power in/out cabinet door (door in door) for low voltage control electronics.

Q. The MV VFD shall contain a power cable termination assembly designed for easy termination and access to line and load cables. The termination assembly cabinet shall allow for top and bottom entry and exit of line and load cables.

R. Power and control terminations and termination strips shall be identified in accordance with schematics and wiring diagrams.

S. The MV VFD shall provide air cooling and condensation protection of its enclosure. The conditioning of the enclosure shall include but not be limited to the following:

1. Air Cooling and Exhaust:

    a. The MV VFD shall be air-cooled unless otherwise specified.

    b. Air-cooled MV VFDs shall be provided with a mixed flow cooling fan, mounted integral to the MV VFD enclosure. The MV VFD shall include, but shall not be limited to, air-flow pressure switches and temperature detectors to monitor proper operation of the air cooling system. If a fan is no longer operational, the system shall generate alarm indication of the fan condition.

    c. Fan motors shall be protected by an input circuit breaker. Metal squirrel cage ball bearing 460 volt three-phase fan motors (or equivalent) with 10 year design life shall be used.

    d. Air filters shall be of a reusable type that shall be able to be easily removed and replaced. Air exhaust from the cooling fans shall be at the top of the enclosure and direct exhaust airflow away from personnel.

    e. A “loss of cooling” shutdown shall be furnished with forced-cooled equipment. In the event of clogged filters or fan shutdown, the drive shall shut down safely without electronic malfunction.

2. Condensation Protection: A temperature controlled space heating resistor per cabinet shall be provided to heat the inside air and to minimize condensation on the elements and walls of the cabinets.

   a. The space heater circuit shall turn on automatically when the drive is not operating.

   b. A fused switch or circuit breaker for the space heater circuit shall be provided for overload protection and as a disconnecting means.

   c. Space heaters elements shall be rated 240 volts AC, single-phase.

T. Finishes: MV VFD exterior and interior structural parts shall be painted per RAL7035. Unpainted steel parts shall be plated with zinc plate/bronze chromate process for corrosion resistance.

2.05 DIODE FRONT END (DFE) RECTIFIER

A. MV VFDs shall utilize vector control with a Diode Front End (DFE) topology. If providing a diode front end configuration, a close-coupled or separately located rectifier transformer shall be offered to maximize flexibility of placement.

B. The MV VFD shall have a diode front end of the press-pack design which shall require pressure to be applied during assembly to minimize the contact between their electric terminals and their proper cooling. The diodes shall be protected by ultra-fast fuses in the event of a short circuit or prolonged overload. Each fuse shall have fusion detection that shall be capable of informing the converter control that a problem has occurred. The rectifier stack shall also be protected against over temperature by a thermostat that shall inform the control once the limit is exceeded.

2.06 ACTIVE FRONT END (AFE) RECTIFIER

A. Active front end rectifiers are not acceptable.

2.07 RECTIFIER DUTY TRANSFORMER

A. For a DFE configuration, the Contractor shall provide a dry-type rectifier duty drive isolation transformer with provisions for a coordinated termination to the MV VFD to provide power conversion from the line voltage to the required MV VFD voltage and to isolate the line from harmonics and common mode voltages. The MV VFD transformer shall operate at 60 hertz +/- 1% of rated frequency with a delta primary winding configuration. The high voltage primary winding shall contain two- 2.5% taps above and two 2.5% taps below the rated voltage. The transformer shall conform to applicable sections of ANSI, IEEE, and NEMA standards.

B. The MV VFD transformer shall be sized for the drive application with a 4160 volt +/- 10% primary winding with a minimum 60 kV basic impulse level (BIL). The low voltage secondary shall have four 2350 volt +/- 10% wye configured windings with a minimum 30 KV basic impulse level (BIL). The MV VFD transformer shall have an 8% impedance with three thermostats for alarm and three thermostats for trip.

C. Factory Impulse Test: The transformer shall be reduced and full wave impulse tested at the factory for all windings above 600 volts.

D. The MV VFD transformer shall be designed to withstand a short circuit. It shall maintain electromagnetic symmetry when only one secondary winding is in short circuit in order to minimize the resulting short circuit forces. The transformer shall be capable of thermally withstanding a short circuit for 2 seconds.

E. Only rectifier grade K-factor transformers shall be utilized, with minimum K-factor of 4 for diode rectifiers. Thyristor type rectifiers shall include K-factor of 12 transformers for variable torque applications and K-factor of 20 for constant torque applications.

F. MV VFD Transformers shall be of a high efficiency type with full load losses of no greater than 2%.

G. The MV VFD transformer shall contain several three-phase secondary windings that shall provide the proper phase shifting to develop a 24-pulse rectification to reduce harmonic currents and voltages reflected to the primary power system.

H. The MV VFD transformer shall have copper conductors with a Class H insulation system (220 degree C) to operate at a temperature rise 150°C at full load conditions. All copper busing (excepting copper coil leads and taps) shall be silver flash or tin plated as approved by manufacturer.

I. All bolted connections shall be made with Belleville washers. The use of Nylock or similar nylon lock nuts is not acceptable for electrical connections. Ground screws and lifting lugs shall be included.

J. Suitable vibration dampers shall be provided with the transformer and its enclosure in order to attenuate mechanical resonance and to reduce the operational sound level.

K. The MV VFD transformer shall include, but shall not be limited to, electrostatic shielding between primary and secondary windings to carry high frequency capacitive currents to ground.

L. The transformer shall be rated for a maximum ambient temperature of 104°F (40°C) with a 30°C average. 3,300 feet maximum altitude and a maximum sound level (AA) of 71 dB(a) at 1 meter. The transformer shall be capable of being close-coupled or separately mounted from the VFD. Where specified, shown, or supplied separately mounted from the VFD, the transformer shall be open type NEMA 1 rated, air-cooled, with top forced ventilation, (cooling fans) to achieve an AA/FA rating.

M. Motor Space Heater:

Circuits shall be provided and sized to coordinate with motor manufacturer. Drawings indicate 120VAC, ASD manufacturer will be required to redesign heater circuit if motor manufacturer supplies 480VAC heaters. Local heater circuit disconnect shall be provided and installed by electrical Contractor.

Heater power will be obtained from the primary 2300 / 4160V power through a tap on an internal transformer.

2.08 CONTROLS AND OPERATOR INTERFACE

A. User Interface: The MV VFD shall have a user-friendly operator interface terminal with the following minimum features:

1. Touch operator screens (minimum 7 inches [179 mm]) that are easy to read and provide “at a glance” indication of drive operating status. Plain English words shall be used for parameters, status, and diagnostic messages. They shall be adjustable for contrast with large characters easily visible in normal ambient light.
2. The operator panel shall include, but shall not be limited to, a local/remote pushbutton selection. Both start/stop source and speed reference shall be independently programmable for keypad, remote I/O, or field bus.
3. A local/remote selector switch and emergency stop pushbutton shall be mounted on the front panel of the MV VFD.

4. Standard advanced programming and troubleshooting functions shall be available by using the MV VFD's Ethernet communication modules and PC based software. In addition the software shall permit control and monitoring of the MV VFD via a personal computer utilizing user-friendly software which shall support monitoring, configuration, diagnostics, control, data recording, and commissioning either locally or remotely when necessary. The system shall run as a web application with no need for any additional software or license on an Owner's PC. Once connected via the Ethernet link, the drive shall supply an Owner's PC with the necessary software. Different password levels shall be available for data and parameter protection. The software shall permit the programming of parameters, display block diagrams, show bar graphs, report adjustment data, display trends, provide troubleshooting using first trip data/trace back data/trouble record, and contain links to system documentation and to system help.

5. Elapsed time indication.

6. Extensive diagnostic functions shall provide separate event and warning queues in non-volatile memory that shall retain information under all conditions.

7. Trend buffers for at least 24 variables that shall allow one-shot or multi-shot trending.

8. Multi-level password access to help ensure that only qualified personnel have access to critical parameters but still allow easy access to other levels of personnel.

9. Extended use of plain language messages to eliminate need to look up error codes or decipher the meaning of error messages.

10. Start-up wizard, including, but not limited to, auto tuning, that shall be interactive and user-friendly.

11. The operator shall be able to navigate through the operator panel menu to choose between the following:

    a. Monitor

    b. Operate

    c. Parameter setup

    d. Actual parameter values

    e. Active trips

    f. Trip history

    g. LCD contrast adjustment

    h. Indication that standard software and optional features software are loaded

12. The following setups and adjustments, at a minimum, shall be available:

    a. Start/stop command from local, remote, or communications port

    b. Speed command from local, remote, or communications port

    c. Motor direction selection

    d. Maximum and minimum speed limits

    e. Acceleration and deceleration times, two settable ranges

    f. Critical (skip) frequency avoidance

    g. Torque limit

    h. Multiple preset speeds adjustment

i. Catch a spinning motor start or normal start selection

j. Programmable analog output

k. PID process controller

B. Monitoring and Displays:

1. The MV VFD operator panel shall be capable of at least showing the following status indicators:

a. Run

b. Forward

c. Reverse

d. Stop

e. Ready

f. Alarm

g. Trip

h. I/O terminal

i. Keypad.

j. Bus/Comm

k. Local (LED)

l. Remote (LED)

m. Event (LED)

2. The MV VFD operator panel shall be capable of displaying the following monitoring functions at a minimum:

a. Output frequency

b. Frequency reference

c. Motor speed

d. Motor current

e. Motor torque

f. Motor power

g. Motor voltage

h. DC bus voltage

i. Unit temperature

j. Calculated motor temperature

k. Voltage level of analog input

l. Current level of analog input

m. Digital inputs status

n. Digital and relay outputs status

o. Analog out

3. Metering shall include GE Multilin's "469 SR Motor Management Relay" or Engineer approved equal. Coordinate with pump motor vendor for temperature, leak detection and vibration setup and trip requirements. Provide information via communication link to SCADA.

C. Inputs and Outputs: The MV VFD shall have the following system interfaces (inputs/outputs):

1. Inputs: A minimum of 10 programmable digital inputs, two Analog inputs, and serial communications interface shall be provided with the following available as a minimum:

   a. Remote manual/auto

   b. Remote start/stop

   c. Remote forward/reverse

   d. Remote preset speeds

   e. Remote external trip

   f. Remote trip reset

   g. Process control speed reference interface, 4-20 mA DC

   h. Potentiometer and 1-10 V DC speed reference interface

2. Outputs: A minimum of 10 programmable relay outputs, and two programmable analog output shall be provided, with the following available at minimum:

   a. Programmable relay outputs with one set of Form C contacts for each, selectable with the following available at minimum:

      1) Trip
      2) Run
      3) Ready
      4) Reversed
      5) Jogging
      6) At speed
      7) Torque limit supervision
      8) Motor rotation direction opposite of commanded
      9) Over temperature

   b. Programmable analog output signal, selectable with the following available at minimum:

      1) Motor current
      2) Output frequency
      3) Frequency reference
      4) Motor speed
      5) Motor torque
      6) Motor power
      7) Motor voltage
      8) DC bus voltage
      9) Analog Output 1 to match Analog Input 1
      10) Analog Output 2 to match Analog Input 2
      11) PT100 temperature
      12) Jog speed

D. Communications:

1. RS232 programming and operation interface port via Serial communications port.

2. As a minimum, interface with specified communication protocols, including Ethernet IP, DeviceNet, ModBus TCP.

3. Provide copper to fiber converter for interface over Ethernet to Stratix switch.

E. Diagnostics:

1. Fiber optic interface boards shall be used to provide gating and diagnostic feedback signals for power semiconductor devices. The diagnostic feedback system shall allow constant control of the device as well as constant monitoring of device health.

2. High speed digital control systems shall continuously monitor hardware and software events including, but not limited to, sensing of power circuit voltage and currents.

3. Power switch device diagnostics shall detect and protect against device short, under gate voltage, loss of gating, loss of diagnostic feedback, and heat sink temperature feedback as well as overload monitoring and protection.

4. Local Diagnostic Features:

   a. Trip history

   b. Record and log trips

   c. Indicate the most recent first, and store up to 100 trips

   d. An emergency-stop (E-stop) shall be provided on the MV VFD door in addition to inputs for remote E-stop command

F. Process Control

1. The MV VFD shall include an onboard process controller capable of being programmed in IEC 61131-3 programming languages. PC based programming software shall be provided with no license fees. The controller shall allow for the logic programming of the MV VFD's inputs and outputs for protection and control.

G. The MV VFD shall have an integrated uninterrupted power system (UPS) for the control modules that, in the absence of external voltage, will supply control voltage to all control modules for a period of time long enough to perform a controlled shutdown of the system. The UPS will be equipped with a rechargeable lithium battery.

2.09 MARKINGS AND LABELING

A. All identification and warning labels and nameplates exterior to the MV VFD shall be resistant to weather, UV, and their intended installation environment.

B. Each MV VFD shall be provided with an engraved nameplate identifying the project specific equipment tag and service description.

C. Warning labels and nameplates shall be present at access locations to advise personnel of possible hazards. The MV VFD shall be marked in accordance with UL, NFPA 70 NEC, NFPA 70E, and other applicable standards.

PART 3 - EXECUTION

3.01 GENERAL

A. In addition to the requirements specified herein, execution shall be in accordance with the requirements of Specification Section 16050 and Drawings.

B. Examine MV VFD exterior and interior prior to installation. Report any damage and do not install any MV VFDs that are structurally, moisture, or mildew damaged.

C. Verification of Conditions: Examine areas and conditions under which the work is to be installed, and notify the Contractor in writing, with a copy to the Owner and the Engineer,

of any conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected.

1. Beginning of the work shall indicate acceptance of the areas and conditions as satisfactory by the Installer.

D. Install variable frequency motor controllers in accordance with reviewed product data, final shop drawings, manufacturer's written instructions and recommendations, and as indicated on the Drawings.

E. Functional testing, commissioning, and first parameter adjusting shall be carried out by a factory trained manufacturer's representative field service engineer. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment. Report to the Engineer any discrepancies or issues with the installation.

F. Provide final protection and maintain conditions in a manner acceptable to the manufacturer that shall help ensure that the variable frequency motor controllers are without damage at time of Substantial Completion.

3.02 FACTORY ACCEPTANCE TESTING

A. Manufacturer standard inspections and tests shall be performed and include but not be limited to the following:

1. The MV VFD manufacturer shall provide testing to validate efficiency, power factor, and harmonic reduction at full load conditions.

2. Warning labels and plates, isolation barriers, and mechanical interlocks shall provide sufficient safety/isolation for personnel and equipment.

3. Bus and bus connections shall be checked for proper clearance, creepage, phasing, and torque.

4. A "HI-POT" dielectric withstand test shall be performed on all buswork and cables from phase-to-phase and phase-to-ground (except solid state components, low voltage controls, and instrument transformers). The voltage level used for this test shall depend on the MV VFD's nominal AC voltage.

5. Components shall be verified against engineering documentation to be present and correctly installed.

6. Printed circuit boards shall be tested prior to MV VFD assembly.

7. Instruments, meters, protective devices, and associated controls shall be functionally tested by applying the specified control signals, current, and/or voltages.

8. Mechanical operation tests shall be performed for each MV VFD to verify satisfactory operation. These tests shall include, but shall not be limited to, checking operating mechanisms and interlock devices.

9. Electrical function tests shall be performed to help ensure proper operation of devices and components. Instrumentation, software, and monitoring tests shall be included.

10. A test record for each MV VFD shall be submitted as part of the O&M manual.

3.03 TRAINING

A. The Contractor shall provide on-site training. The training shall include, but shall not be limited to, instruction on assembly and major components. The training sessions shall be designed for maintenance and operations personnel with training that is specific to the system installed at the Owner's facility. Training shall include, but shall not be limited to, troubleshooting and maintenance of the medium voltage drives installed. Training

session duration shall be sufficient to adequately cover the topics listed. Manuals and documentation shall be provided to each participant. At a minimum, the training shall cover the following topics:

1. Theory of operation
2. Key operations including, but not limited to, motor(s)
3. Drive hardware and firmware
4. Cooling system requirements
5. Operator interfaces (local and remote)
6. Printed circuit board maintenance and replacement
7. Power device maintenance and replacement
8. Trip analysis and troubleshooting procedures/codes
9. Preventative maintenance routines
10. Drive PC based software tool and its operational, maintenance, and diagnostic features

B. The Contractor shall provide on-site training consisting of 2 separately scheduled session(s) each for a class of [8] Owner's staff a period of not less than 2 hours.

3.04 FUNCTIONAL DEMONSTRATION TESTING

A. The Contractor shall certify in writing prior to scheduling functional demonstration testing that the equipment has been installed, adjusted, and tested in accordance with the manufacturer's recommendations and is ready for operation.

B. The Contractor shall demonstrate the functional and operational features of the variable speed motor controller along with the driven equipment.

END OF SECTION

SECTION 16446 - VARIABLE FREQUENCY DRIVES

PART 1 - GENERAL

1.01 REFERENCES

A. The drive shall be designed to meet the following specifications:

1. NFPA 70 - US National Electrical Code

2. NEMA ICS 3.1 - Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable Speed Drive Systems

3. NEMA 250 - Enclosures for Electrical Equipment

4. UL 508C – Underwriter's Laboratory

5. CAN/CSA-C22 No. 14-M91 - Canadian Standards Association

6. IEC 146 - International Electrical Code

1.02 REGULATORY REQUIREMENTS

A. The drive shall conform to the following requirements:

1. NFPA 70

2. IEC 146

3. EN Standard/CE marked for EMC directives

Emissions	Immunity
EN 50081-1	EN 50082-1
EN 50081-2	EN 50082-2
EN 55011 Class A	IEC 801-1,2,3,4,6,8
EN 55011 Class B	(per EN 50082-1,2)

4. EN Standard/CE marked for Low Voltage directives

   EN 60204-1
   PREN 50178

5. IEC 801

6. C-UL marking to provide an approved listing for both United States and Canadian users.

1.03 QUALIFICATIONS

A. Manufacturer: The drive manufacturer shall have been in the drive business continuously for a minimum of 15 years and specialize in the design and manufacturing of PWM Adjustable Frequency Drives.

B. Support: The drive manufacturer shall maintain factory trained and authorized service facilities for their drives within 100 miles of the project and have a demonstrated record of service for at least the previous three years. Full-time support personnel shall be employed by the drive manufacturer.

C. Certification: All drives must be assembled at locations that are certified to the ISO-9001

Series of Quality Standards. This insures all quality and corrective action procedures are documented and implemented with a goal of Total Customer Satisfaction.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Square D,” “Eaton,” “Robicon,” “Allen Bradley”, or approved equal.

2.02 RATINGS

A. Input Power: The drive is self adjustable to accept an input voltage range between 200-240/380-480/500-600VAC, three phase +/-10%.

Displacement power factor shall range between 1.0 and 0.95, lagging, over the entire speed range (0.80 for 0.5-5hp/0.37-3.7kW, 200-480V drives). The efficiency of the drive shall be a minimum of 97% at full load and speed.

B. Environment: Storage ambient temperature range: -40 to 70 C (-40 to 158 F). Operating ambient temperature range: 0 to 40 C (0 to 109 F) without derating. The relative humidity range is 5% to 95% non-condensing.

Operating elevation: up to 1000 Meters (3,300ft) without derating.

C. Output Power: The output voltage is adjustable from 0 to rated input voltage. The output frequency range is adjustable from 0 to 400 Hz. The inverter section will produce a pulse width modulated (PWM) waveform using latest generation IGBTs.

2.03 DESIGN

A. Hardware: The drive hardware shall employ the following power components:

1. Diode or fully gated bridge on the input.
2. DC bus inductor on all ratings 5.5kW (7.5HP) or greater.
3. Switching logic power supply operating from the DC bus.
4. Phase to phase and phase to ground MOV protection.
5. Gold plated plug-in connections on printed circuit boards.
6. Microprocessor based inverter logic isolated from power circuits.
7. Latest generation IGBT inverter section.
8. Inverter section shall not require commutation capacitors.
9. Customer Interface common for all horsepower ratings. Interface shall include an LCD digital display, programming keypad and operator keys option.
10. Main Control Board common for 5.5kW (7.5HP) and up.
11. Common control connection for all ratings.
12. Optimized for 4kHz carrier frequency at 44kW (60HP) or less, and 2kHz at 55kW (75 HP) and larger.

13. Peripheral Interface to enable attaching common options.

B. Control Logic: The drive shall be programmable or self adjusting for operation under the following conditions:

1. Operate drive with motor disconnected.

2. Controlled shut down, when properly fused, with no component failure in the event of an output phase to phase or phase to ground short circuit and annunciation of the fault condition.

3. Adjustable PWM carrier frequency within a range of 2-8kHz.

4. Selectable Sensorless Vector or V/Hz mode.

5. Selectable for variable or constant torque loads. Selection of variable torque provides 110% of rated VT current for up to one minute. Selection of constant torque provides 150% of rated CT current for up to one minute.

6. Multiple programmable stop modes including - Ramp, Coast, DC-Brake, Ramp-to-Hold and S-curve.

7. Multiple acceleration and deceleration rates.

8. Multiple acceleration and deceleration rates.

9. All adjustments to be made with the door closed.

10. Adjustable output frequency up to 400Hz.

C. POWER CONDITIONING: The drive shall be designed to operate on an AC line which may contain line notching and up to 10% harmonic distortion. 3% input line reactors are required on all drives 25 HP or larger.

D. Output (load) filters shall be required on all VFDs whose distance to motor terminals exceeds 200 feet or the sum of the lengths of parallel runs of one phase exceeds 200 feet. 3% load reactors shall be provided on all VFDs less than 200 feet to motor terminals.

2.04 FEATURES

A. Interface: The drive shall provide a removable Human Interface Module with integral display to show drive operating conditions, adjustments and fault indications. The display shall be removable under power without causing a fault and is visible and operable without opening the enclosure door. The display shall consist of 2 lines of 16 character alphanumeric, backlit LCD with the display being configurable for simultaneously displaying two values using customized multi-lingual text and user scaled units. The module shall provide LED indication of drive direction and commanded direction. The display shall be capable of remote mounting by means of cable connection up to 10 meters (33ft) from the drive and is capable of being used as a hand-held terminal.

B. Control Mode: Programming shall provide the ability to select sensorless vector or v/hz mode. The sensorless vector mode shall use motor nameplate data plus motor operating data, such as IR drop, nominal flux current and flux up time. The volts per hertz mode shall be able to be programmed for squared, cubed, straight line, pre programmed or full custom patterns.

C. Current Limit: Programmable current limit shall be available from 20% to 160% of constant torque rating. Current limit shall be active for all drive states; accelerating, constant speed and decelerating. The drive shall employ PI regulation with an adjustable gain for smooth

transition in and out of current limit.

D. Acceleration/Deceleration: Accel/Decel settings shall provide separate adjustments to allow either setting to be adjusted from 0 seconds to 3600 seconds. A second set of remotely selectable Accel/Decel settings shall be accessible with Control Interface option. An adaptive current limit circuit shall be able to be disabled in programming for fast acceleration of low inertia loads.

E. Speed Regulation: The programmable speed regulation modes shall include the following:

1. Open Loop

2. Slip Compensation with 0.5% speed regulation

3. Droop - Negative Slip Compensation with 0.5% speed regulation

4. Traverse Function

5. Closed loop encoder feedback with 0.1% speed regulation

6. Process PI control

F. Speed Profiles: Programming capability shall allow the user to produce speed profiles with linear acceleration/deceleration or "S-Curve" profiles that provide changing accel/decel rates. S-Curve profiles shall be selectable for fixed or adjustable values.

G. Adjustments: The digital interface shall be provided for all set-up, operation and adjustment settings. All adjustments are shall be stored in nonvolatile memory (EEPROM). Potentiometer adjustments are not acceptable. The drive shall provide EEPROM memory for factory default values.

H. Process PI Control: An internal process PI regulator shall have both proportional and integral gain adjustments as well as error inversion and output clamping functions. The feedback may be configured for normal or square root functions. If the feedback indicates that the process is moving away from the setpoint, the regulator will adjust the drive output until the feedback equals the reference. Process control shall be enabled or disabled with a hardwire input. Transitioning in and out of process control shall be able to be tuned for faster response by preloading the integrator. Protection shall be provided for a loss of feedback or reference signal.

I. Fault Reset/Run: The drive shall have the ability to conduct up to nine automatic fault reset and restarts following a fault condition before locking out and requiring manual restart. The automatic mode is not applicable to a ground fault, shorted output faults and other internal microprocessor faults. The time between restarts shall be adjustable from 0.5 seconds to 30 seconds.

J. Skip Frequencies: The drive shall contain three adjustable set points that lock out continuous operation at frequencies which may produce mechanical resonance. The set points shall have a bandwidth adjustable from 0Hz to 15Hz.

K. Run On Power Up: A user programmable restart function shall be provided to automatically restart the equipment after restoration of power after an outage. A maintained 2-wire start input is required for this function.

L. Line Loss Restart: This programmable function shall be provided to select the reconnect mode of the drive after recovery from a line loss condition. The reconnect modes shall be B Last Speed, Speed Search, Track Volts, or Use Encoder. Disabling this feature shall force the drive to start from zero hertz.

M. Fault Memory: The last four faults as well as operating frequency, drive status and power mode shall be stored at the time of fault. Information shall be maintained in the event of a power loss.

N. Overload Protection: The drive shall provide Class 20 motor overload protection investigated by UL to comply with N.E.C. Article 430. Overload protection shall be speed sensitive and adjustable for motors with speed ranges of 2:1, 4:1 and 10:1. A viewable parameter shall store the overload usage in percent. An alarm bit can be used to adjust a process to eliminate an overload trip.

O. Auto Economizer: This feature shall automatically reduce the output voltage when the drive is operating in an idle mode (drive output current less than programmed motor FLA). The voltage shall be reduced to minimize flux current in a lightly loaded motor thus reducing kW usage. If the load increases, the drive shall automatically return to normal operation.

P. Terminal Blocks: Separate terminal blocks shall be provided for control and power wiring.

Q. Flying Start: The drive shall be capable of determining the speed and direction of a spinning motor and adjust its output to "pick-up" the motor at the rotating speed. The flying start feature shall be operable with or without encoder feedback.

R. Ride Through: The control logic shall be capable of "riding through" a power outage of up to 2 seconds in duration.

S. Analog Output: An output signal shall be provided and be jumper selectable for 0 - 10V DC or 0 - 20 mA which is user programmable such that it is proportional to one of 13 process parameters including output frequency, output current, encoder feedback, output power and others. A programmable offset shall be provided to allow modification of the analog output to obtain 2 - 10V DC or 4 - 20 mA. Programmable gain adjustments for both upper and lower settings shall allow for system calibration.

T. Reference Signals: The drive shall be capable of the following input reference signals:

Digital pulse input	Digital MOP
Remote potentiometer	Ethernet
10V DC	HIM (Program/Control panel)
4-20 mA	DeviceNet (As alternative to Ethernet Communication)

U. Loss of Reference: In the event of loss of the 4 - 20 mA reference signal, or loss of communication, the drive shall be user programmable to the following:

Fault and stop
Alarm and maintain last reference within 10%
Alarm and go to preset speed
Alarm and go to minimum speed
Alarm and go to maximum speed
Active for Process PI reference or feedback

V. Digital I/O: Contact output ratings shall be 115V AC/30V DC, 5.0 Amp resistive, 2.0 Amp inductive. All four contacts provided shall be programmable to 17 different conditions. Factory settings shall be as follows:

Form A Run contact
Form C Fault contact
Form C Alarm contact
Form A at Speed contact

W. Operator Devices, and Control Interface: Provide start and stop controls integrally with the

drive. Also provide control interface cards as required to accommodate the external control devices shown in Control Circuits.

X. Backspin Protection: Delay timer or motor protection relay that prevents the motor from starting immediately following a stop command or loss of power. The backspin protection time shall be field adjustable.

Y. Above 150HP provide vibration monitoring for upper and lower bearing of pump motors with communication to SCADA.

Z. Above 15HP provide discrete inputs for temperature switches, two per winding, and leak detection discrete inputs with alarming to SCADA.

AA. Minimum Control Features:

1. Local – Remote selection of Start / Stop control.

2. Local / Remote selection of Speed control.

3. Accept a grounded, isolated, 4-20 mA input remote speed control signal from an external device.

4. Provide a 4-20mA output signal proportion to VFD output frequency for remote speed indication.

5. As a minimum, interface with specified communication protocols, including Ethernet IP, DeviceNet, ModBus TCP.

6. Provide copper to fiber converter for interface over Ethernet to stratix switch.

2.05 HARMONIC DISTORTION SUPPRESSION

A. A comprehensive pre-equipment-selection harmonic study shall be prepared by the Contractor. The results of this pre-equipment selection study shall be submitted to the Engineer as part of the submittals specified herein. Should this study indicate the need for tuned filters, line reactors, isolation transformers, or other harmonic distortion suppression equipment, these shall be supplied at no additional cost to the Owner. Indicate the location of the harmonic suppression equipment in the submittal data. Location is subject to acceptance by the Engineer.

B. The harmonic distortion values resulting from operation of all or any variable frequency drive-driven motor-load combinations operating at full load shall be as defined in IEEE Standard 519.

1. Maximum allowable total harmonic voltage distortion (THD): 5 percent of the fundamental.

2. Maximum allowable individual frequency harmonic voltage distortion: within the limits of IEEE standard 519.

3. Maximum allowable total demand distortion (TDD): within the limits of IEEE Standard 519-1992, Table 10.3.

4. Maximum allowable individual frequency harmonic demand distortion: within the limits of IEEE Standard 519-1992, Table 10.3.

5. The harmonic distortion levels shall be specific to the "Point of Common Coupling" (PCC) as defined in IEEE Standard 519 and indicated on the Drawings.

C. System single line diagrams and field access to the site will be provided to the Contractor for the purpose of providing this study. Contractor shall obtain from others other information that may be necessary to perform this study. Input data and other pertinent information used in harmonic study shall be coordinated by the Contractor with the following:

1. Input data/information/results of the short circuit fault analysis specified herein.

2. Electrical system configuration and electrical equipment shop drawing submittal data including, but not being limited to new non-linear loads, new linear loads, and new capacitors.

D. Preparation of this pre-equipment selection study does not relieve the requirement for the Contractor to perform and submit the results of a second, final comprehensive study prepared by a recognized independent authority acceptable to the Owner after equipment installation.

E. In addition, the Contractor shall field measure actual harmonic distortion and verify with tests performed by an independent authority acceptable to the Owner after satisfactory full-load operation.

F. As part of the specified harmonic studies and other work for this project, identify and correct resonance conditions in the electrical distribution system at no additional cost to the Owner. Shop drawings, data, location of the respective equipment and its connection to the electrical distribution system shall be acceptable to the Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Comply with manufacturer's recommendations, except as modified herein.

B. Drives shall be adjusted such that maximum speed is motor nameplate RPM, and minimum speed is just high enough to provided motor driven equipment cooling.

C. Where a disconnect is provided for a motor controlled via VFD, Provide warning label on disconnect: "Do not open under load"

3.02 START-UP, TRAINING, AND TESTING

A. The drive manufacturer shall provided factory authorized, trained service personnel for start-up and testing. Upon successful completion of installation and testing, training shall be provided in accordance with 16050.

3.03 TOOLS AND SPARE PARTS

A. Any special tools required for normal operation and maintenance shall be provided by the equipment manufacturer.

B. Furnish the following spare parts:

1. Ten fuses for each type used.

2. Ten lamps for each type used.

END OF SECTION

SECTION 16460 - SMALL POWER AND MISCELLANEOUS TRANSFORMERS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Transformer locations and size shall be as shown on the Contract Drawings, as specified herein.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Square D”, “Cutler Hammer”, “ABB” or approved equal.

2.02 FABRICATION

A. General Purpose Dry-Type Transformers

1. Single phase transformers shall be 480 volt primary and 120/240 volt secondary. Three phase transformers shall be 480 volts delta primary and 208 Y/120 or 240 volt delta secondary. Transformers 25 KVA and larger shall have a minimum of 4 (2 above, 2 below) 2 1/2 percent full capacity primary taps.

2. Transformers shall be 150 degrees Celsius temperature rise above a 40 degrees Celsius ambient. All insulating materials are to be in accordance with the latest NEMA Standards for a 220 degrees Celsius UL recognized insulation system.

3. Transformer coils shall be of the continuous wire wound construction and shall be impregnated with non-hygroscopic, thermo-setting varnish. The coils shall also have a final wrap of electrical insulating material to prevent mechanical injury to the wire as well as increasing the electrical breakdown strength.

4. All cores shall be constructed of high grade, non-aging silicon steel with high magnetic permeability, and low hysteresis and eddy current losses. Magnetic flux densities are to be kept well below the saturation point. The core laminations shall be clamped together with steel angles. The completed core and coil shall then be bolted to the base of the enclosure but isolated from the base by means of rubber, vibration absorbing mounts. There shall be no metal-to-metal contact between the core and coil to the enclosure. On transformers 500 KVA and smaller, the vibration isolation system shall be designed to provide a permanent fastening of the core and coil to the enclosure. To further facilitate vibration and noise isolation, the final section of conduit to the transformer shall be flexible.

5. Transformers 25 KVA and larger shall be in heavy gauge, sheet steel, ventilated enclosures. The ventilating openings shall be designed to prevent accidental access to live parts in accordance with UL, NEMA, and National Electrical Code Standards for ventilated enclosures. Transformers 25 KVA through 75 KVA shall be designed so they can either be floor or wall mounted. Above 75 KVA they shall be of the floor mounted design.

6. The entire transformer enclosure shall be degreased, cleaned, phosphatized, primed, and finished in the same color as the motor control equipment. For more details see Division 9 of these Specifications.

7. The maximum temperature of the top of the enclosure shall not exceed 50 degrees Celsius rise above a 40 degrees Celsius ambient.

8. The core of the transformer shall be visibly grounded to the enclosure by means of a flexible grounding conductor sized in accordance with NEMA and NEC Standards.

9. The transformer shall be marked “DANGER HIGH VOLTAGE” with labels specified in the section on marking, this Division.

10. The transformers shall be manufactured to requirements of applicable standards, especially as they apply to noise level and surface temperatures.

PART 3 - EXECUTION

3.01 INSTALLATION / APPLICATION / ERECTION

A. Transformers shall be rigidly mounted to the structure or the foundation in the case of freestanding units.

B. Transformers shall be megger tested prior to energization.

C. Transformers with taps shall be adjusted to supply the nominal service voltage required on the secondary.

D. Transformers shall be installed in accordance with NEC requirements and manufacturer recommendations.

END OF SECTION

SECTION 16495 - SWITCHBOARD MATTING

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Switchboard matting shall be furnished by the Contractor and placed in front of all power distribution and control equipment.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Switchboard matting shall be W.H. Salisbury & Company, Wearwell, Erico, or equal.

2.02 MATERIALS

A. Switchboard matting shall be nonconductive with a minimum of 40,000 volts dielectric strength. The mat shall have a corrugated, non-slip surface and shall be a minimum of 1/4 inch thick. Width shall be 36 inches and length shall be as required at each location. The mat shall be black in color, ozone and oil resistant, and manufactured to meet all applicable ANSI/ASTM standards.

PART 3 – EXECUTION (NOT USED)

END OF SECTION

SECTION 16496 - AUTOMATIC TRANSFER SWITCH (Low Voltage Units)

PART 1 - GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall furnish, install, connect, test and place in satisfactory operation automatic transfer switches as specified herein and indicated in Drawings.

B. All devices and components of the automatic transfer switch shall be NEMA rated. IEC rated devices are unacceptable and shall be cause for rejection of the submittals/equipment.

1.02 TESTING

A. All tests shall be performed in accordance with the requirements of the General Conditions and Division 1. The following tests are required include, but are not limited to:

1. Witnessed Shop Tests

    a. None required

2. Certified Shop Tests and Reports

    a. Automatic transfer switches shall be given routine factory tests. The factory tests shall demonstrate that the completed switches function correctly and that the required timing has been set. Certification of these settings shall be submitted to the Engineer upon request.
    b. Test procedures shall be in accordance with UL-1008. During the 30 cycle withstand tests, there shall be no contact welding or damage.
    c. The thirty cycle tests shall be performed without the use of current limiting fuses.
    d. Oscillograph traces across the main contacts shall verify that contact separation has not occurred and there is contact continuity across all phases after completion of the test.
    e. When conducting temperature rise tests in accordance with UL-1008, include post-endurance temperature rise tests to verify the ability of the transfer switch to carry full rated current after completing the overload and endurance tests.
    f. Manufacturer shall submit test reports upon request.

3. Field Tests

    a. Electrical contractor shall establish conductor phasing prior to testing.
    b. Prior to performance testing, transfer switch field technician shall:
        1) Program all time delays.
        2) Program all parameter threshold setpoints.
        3) Check all field power wiring.
        4) Coordinate with Electrical Contractor to verify correct termination points for all SCADA signals required by the Contract.
        5) For those installations utilizing network communications, the field technician shall coordinate with system integrator to establish communication link is functional.
    c. Transfer switch field technician shall execute unloaded test simulation by performing no-load test from transfer switch. Upon completion of simulated test, note generator cool down operation.
    d. Transfer switch field technician shall execute loaded test from transfer switch to power the maximum facility load that can be exercised at the time of the test. The technician shall:
        1) Confirm all metering data is displayed correctly.
        2) Confirm switch position status and source status indicators display correctly.
        3) Confirm all delay timing functions operated properly.
        4) Coordinate with Electrical Contractor to verify transmission of SCADA signals.
    e. During load test, Electrical Contractor shall perform infrared scanning of power wiring

terminations and document results.

f. Failure of the transfer switch to operate properly during tests shall be corrected and the test repeated.

1.03 SUBMITTALS

A. In accordance with the procedures and requirements set forth in the General Conditions and Section 01300, Submittals, the Contractor shall obtain from the equipment manufacturer and submit the following:

1. Shop Drawings
2. Operation and Maintenance Manuals
3. Spare Parts Lists
4. Special Tools List
5. Reports of certified shop tests shall be submitted which indicates a closing and withstand ampere rating as required based on short circuit study requirements. Rating shall be symmetrical, 30 cycles at 480 VAC.
6. Report indicating transfer switch performance testing was completed satisfactorily including a data sheet with the values of all programmed parameters as left upon completion of testing.
7. Guarantee/Warranty Program

B. Each submittal shall be identified by the applicable specification section.

1.04 SHOP DRAWINGS

A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.

B. Partial, incomplete or illegible submittals will be returned to the Contractor for resubmittal without review.

C. Shop drawings for each automatic transfer switch shall include but not be limited to:

1. Product data sheets.
2. Complete assembly, layout, and installation drawings with clearly marked dimensions and conduit entrance locations.
3. Example equipment nameplate data sheet.
4. Complete internal schematic and interconnecting wiring diagrams. Standard wiring diagrams that are not custom created by the manufacturer for the automatic transfer switch for this project are not acceptable.
5. Nameplate schedule.
6. Manufacturer's standard installation instructions.
7. Manufacturer's standard warranty.

D. The shop drawing information shall be complete and organized in such a way that the Engineer can determine if the requirements of these specifications are being met. Copies of technical bulletins, technical data sheets from "soft-cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the Contractor intends to provide are acceptable and shall be submitted.

E. Prior to completion and final acceptance of the project, the Contractor shall furnish and install "as-built" wiring diagrams for each automatic transfer switch. These final drawings shall be plastic laminated and securely placed inside each transfer switch and included in the O&M manuals.

1.05 OPERATION AND MAINTENANCE MANUALS

A. The Contractor shall submit operation and maintenance manuals in accordance with the procedures and requirements set forth in the General Conditions and Division 1.

1.06 TOOLS, SUPPLIES AND SPARE PARTS

A. The automatic transfer switches shall be furnished with all special tools necessary to disassemble, service, repair and adjust the equipment. All spare parts as recommended by the equipment manufacturer shall be furnished to the Owner by the Contractor.

B. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.

C. Spare parts shall be delivered at the same time as the equipment to which they pertain. The Contractor shall properly store and safeguard such spare parts until completion of the work, at which time they shall be delivered to the Owner.

D. Spare parts lists, included with the shop drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.

E. Parts shall be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part shall be properly identified by a separate number. Those parts which are identical for more than one size, shall have the same parts number.

1.07 SERVICES OF MANUFACTURER'S REPRESENTATIVE

A. The Contractor shall provide the services of a qualified manufacturer's technical representative who shall adequately supervise the installation and testing of all equipment furnished under this Contract and instruct the Contractor's personnel and the Owner's operating personnel in its maintenance and operation. The services of the manufacturer's representative shall be provided for a period of not less than as follows:

1. One trip of one (1) working day during installation of the equipment.
2. On trip of one (1) working day to program parameters and test transfer switch in conjunction with standby generator as indicated under paragraph 1.02.A.3, Field Tests.
3. One trip of one (1) working day after acceptance of the equipment.
4. One trip of one (1) working day during the warranty period.

B. Any additional time required to achieve successful installation and operation shall be at the expense of the Contractor.

C. The manufacturer shall have an established network of service centers capable of servicing the specified equipment. The manufacturer shall have a service center within 200 miles of the project site which shall stock parts necessary to service the switch. The manufacturer shall include a toll-free telephone number for a field service contact affixed to each enclosure.

D. Service center personnel shall be on call 24 hours a day, 365 days a year. Personnel shall be factory trained and certified in the maintenance and repair of the specified equipment.

E. After warranty service contracts shall be made available to the Owner by the manufacturer, through the service centers, to provide periodic maintenance and/or repair of the specified equipment.

1.08 IDENTIFICATION

A. Each automatic transfer switch shall be identified with the identification number indicated on the Drawings (e.g. ATS-FB, etc.). A lamacoid nameplate with black lettering on white background shall be securely affixed in a conspicuous place on each switch.

1.09 TRAINING

A. The Contractor shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory trained specialists who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section.

B. Provide the services of an experienced, factory trained technician or service engineer of the switch manufacturer at the jobsite for minimum of four (4) hours for training of Owner personnel, beginning at a date mutually agreeable to the Contractor and the Owner. The training shall include:
   1. Description of the operating parts of the transfer switch.
   2. Description of the various menus and parameters in the operator display and demonstration of how to navigate through the menus and parameters.
   3. Demonstration of how change programmed parameters.
   4. Description of metering data available (if applicable) and demonstration of how to display them.
   5. Demonstration of how to display and reset alarms and faults.
   6. Troubleshooting to remedy faults.
   7. Other subjects as may be requested by Owner.

1.10 WARRANTY

A. The manufacturer shall warrant each automatic transfer switch for a minimum of five (5) years from date of shipment. In addition, the manufacturer shall repair or replace equipment found faulty under the terms of the warranty. The manufacturer shall submit data outlining the guarantee/warranty program.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. The equipment covered by this Specification is intended to be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, constructed and installed in accordance with the best practices of the trade, and shall operate satisfactorily when installed as shown on the Drawings.

B. The equipment described herein, as a minimum, shall meet all of the requirements specified in this Section and shall be a product of a manufacturer who has produced automatic transfer switches for a period of at least five (5) years. The equipment shall be compatible with the loads to be served. Assembly of the switches by a fabricator is not acceptable.

C. The manufacturer of the automatic transfer switch shall verify that the switches are listed by Underwriters Laboratories, Inc., standard UL-1008, with 30-cycle withstand and close-in values as indicated on the Drawings or specified herein.

D. The automatic transfer switches shall be Model RTS-30 as manufactured by Russelectric, Inc., or equivalent. The basis of design is the Russelectric RTS-30.

2.02 AUTOMATIC TRANSFER SWITCH

A. General

   1. Switches shall have ampere ratings and number of poles as indicated on the Drawings and shall be suitable for 480 VAC, three-phase, 60 Hertz operation.
   2. For three phase, four-wire systems where a neutral is required, a true four-pole switch shall be supplied with all four electrically and mechanically identical poles mounted on a common shaft. The continuous current rating and the closing and withstand rating of the fourth pole

shall be identical to the rating of the main poles.
3. The transfer switch shall have both top and bottom mounted cable access.
4. The switch shall be capable of switching all classes of load and rated for continuous duty when installed in a non-ventilated enclosure.
5. The 30-cycle closing and withstand current rating of the switch shall be 42,000 amperes RMS (minimum). This rating shall not be restricted by the use of a specific manufacturer's circuit breaker.
6. This switch shall be complete with all accessories and listed by UL under Standard UL-1008 for use on emergency systems.
7. All bolted bus connections shall have Belleville compression type washers. Switches for four-wire systems shall be furnished with a fully rated solid neutral bus.
8. The switch shall be equipped with 90°C rated copper/aluminum solderless mechanical type lugs of the proper quantity and size to accommodate the termination of field wiring.
9. Switches shall be capable of normal operation during and after seismic loading. Seismic loading shall not cause false operation.

B. Design Requirements

1. The switch shall utilize dual operators. Operators shall provide for an adjustable neutral off position in which the load is disconnected from both sources during transfer from utility to generator and re-transfer back the utility.
2. Switches shall be capable of transferring successfully in either direction with 70 percent of rated voltage applied to the terminals.
3. The time delay between the opening of the closed contacts and the closing of the open contacts shall allow for voltage decay before transfer, allowing the motor and transformer loads to be re-energized after transfer with normal in-rush current. Switches using in-phase monitors are not acceptable.
4. Normal and standby contacts shall be positively interlocked mechanically and electrically to prevent simultaneous closing. Main contacts to be of silver-tungsten alloy, mechanically locked in position in both the normal and standby positions without the use of hooks, latches, or magnets. Provide separate arcing contacts, with magnetic blowouts on each pole. Interlocked molded case circuit breaker switches or contactors are not acceptable.
5. Equip the transfer switch with a permanently attached, safe, manual operator designed to prevent injury to personnel in the event the electrical operator should become energized during manual transfer. The manual operator shall provide the same contact-to-contact transfer speed as the electrical operator to prevent a flashover from slowly switching the main contacts and shall be operable with the transfer switch enclosure door closed.

C. Sequence of Operation

1. Should the voltage on any phase of the normal source drop below 80 percent or increase to 120 percent, or frequency drops below 90 percent, or increase to 110 percent, or 20 percent voltage differential between phases occur, after a programmable time delay period of 0-9999 seconds factory set at three (3) seconds to allow for momentary dips, the engine starting contact(s) shall close to start the standby plant or connect to the standby source.
2. Transfer to the standby power source shall occur when 90 percent of rated voltage and frequency has been reached by the standby power source.
3. After restoration of normal power on all phases to a preset value of 90 percent to 110 percent of rated voltage, at least 95 percent to 105 percent of rated frequency, and voltage differential is below 20 percent between phases, an adjustable time delay period of 0-9999 seconds factory set at 300 seconds shall delay the transfer to allow stabilization of the normal source. Should the standby source fail during this time delay period, the switch shall automatically retransfer to the normal source.
4. After retransfer to the normal power source, the standby plant shall operate at no load for a programmable period of 0-9999 seconds factory set at 300 seconds. Should the normal power source fail during this time delay period, the transfer switch shall automatically return to the standby source.

D. Controls

1. The transfer switch shall be equipped with a microprocessor-based control system to provide all the operational functions of the automatic transfer switch. The controller shall have a real time clock with Nicad battery back-up.
2. The CPU shall be equipped with self-diagnostics which perform periodic checks of the memory, I/O, and communication circuits with a watchdog power fail circuit.
3. The controller shall include a Modbus TCP/IP Ethernet communication port for interfacing with the Generator (vendor supplied) and Owner's SCADA system. Refer to specification section 16620, Generator and specification section 18100, I/O list for list of Generator signals communicated to the Owner's SCADA system via the automatic transfer switch panel.
4. The controller shall have password protection to limit access to authorized personnel.
5. The controller shall include a 20 character LCD display with a keypad, which allows access to the system.
6. The controller shall include three-phase over/under voltage, over/under frequency, phase sequence detection, and phase differential monitoring on both normal and standby sources.
7. The controller shall be capable of storing the following records in memory for access either locally or remotely:

    a. Number of hours the transfer switch is in the standby position (total since record reset).
    b. Number of hours standby power source is available (total since record reset).
    c. Total transfer in either direction (total since record reset).
    d. Date, time, and description of the last four source failures.
    e. Date of the last exercise period.
    f. Date of record reset.

8. Controller shall indicate:

    a. Switch is in normal position
    b. Switch is in standby position.
    c. Controller is running.

9. An LCD readout shall display both normal source and standby source availability.

10. The microprocessor controller shall meet the following requirements:

    a. Storage conditions - 25°C to 85°C
    b. Operation conditions - 20°C to 70°C ambient
    c. Humidity 0 to 99% relative humidity, non-condensing
    d. Capable of withstanding infinite power interruptions
    e. Surge withstand per ANSI/IEEE C-37.90A-1978

11. All control wiring shall be 18 gauge (minimum), 600 VAC, SIS switchboard type. All control wiring shall be identified at each termination (both ends) using tubular, sleeve-type wire markers.

12. The automatic transfer switch controller shall be a Model RPTCS as manufactured by Russelectric, GE Zenith Controls equivalent, or ASCO equivalent. The controller shall be programmed by the manufacturer's field representative during start-up and testing in conjunction with standby generator.

E. Metering

1. The transfer switch shall provide for metering of phase-to-phase and phase-to-neutral voltage and frequency of both normal and emergency sources as standard. Optional phase and neutral current shall also be provided. The controller shall calculate voltage unbalance, accumulated energy (KWH, KVAH, KVARH), instantaneous real, apparent, and reactive power (KW, KVA, KVAR), and power factor (PF). All measured electrical parameters and calculated

values shall be available to the Owner's SCADA system via the controller Ethernet communication port.

F. Accessories

1. Programmable three phase sensing of the normal source set to pickup at 90% and dropout at 80% of rated voltage and overvoltage to pickup at 120% and dropout out at 110% of rated voltage. Programmable frequency pickup at 95% and dropout at 90% and over frequency to pickup at 110% and dropout at 105% of rated frequency. Programmable voltage differential between phases, set at 20%, and phase sequence monitoring.
2. Programmable three phase sensing of the standby source set to pickup at 90% and dropout at 80% of rated voltage and overvoltage to pickup at 120% and dropout out at 110% of rated voltage. Programmable frequency pickup at 95% and dropout at 90% and over frequency to pickup at 110% and dropout at 105% of rated frequency. Programmable voltage differential between phases, set at 20%, and phase sequence monitoring.
3. Time delay for override of momentary normal source power outages (delays engine start signal and transfer switch operation). Programmable 0-9999 seconds. Factory set at 3 seconds.
4. Time delay on retransfer to normal, programmable 0-9999 seconds, factory set at 300 seconds, with overrun to provide programmable 0-9999 second time delay, factory set at 300 seconds, unloaded engine operation after retransfer to normal.
5. Time delay on transfer to standby, programmable 0-9999 seconds, factory set at 3 seconds.
6. A maintained type load test switch shall be included to simulate a normal power failure, keypad initiated.
7. A time delay bypass on retransfer to normal shall be included. Keypad initiated.
8. Contact, rated 10 A at 30VDC, to close on failure of normal source to initiate engine starting.
9. A plant exerciser shall be provided with (10) 7 day events, programmable for any day of the week and (24) calendar events, programmable for any month/day, to automatically exercise the standby plant programmable in one minute increments. Also include a control switch for selection of either "no load" (switch will not transfer) or "load" (switch will transfer) during the exercise period. Keypad initiated.
10. Relay contacts which close when normal source fails wired to a terminal strip.
11. Relay contacts which open when normal source fails wired to a terminal strip.
12. Relay contacts which close when emergency source is available wired to a terminal strip.
13. Relay contacts which open when emergency source is available wired to terminal strip.
14. Two auxiliary contacts rated 15 A at 120 VAC on main shaft, closed on normal and wired to a terminal strip.
15. Two auxiliary contacts rated 15 A at 120 VAC on main shaft, closed on standby and wired to a terminal strip.
16. Provide a preferred source selector switch to permit the selection of either source as the "preferred" source which the ATS will always seek if that source is available. The two-position selector switch shall have a legend plate which reads "Source A/Source B." Selector switch shall only be provided for the indoor transfer switches at the plant site.

2.03 ENCLOSURES

A. The transfer switches shown to be installed indoors shall be housed in a NEMA 1 (gasketed) enclosure fabricated from 12-gauge steel. The enclosure shall exceed the UL-1008 minimum wire bending space requirements. The enclosure shall be equipped with an internal, welded steel, door-mounted print pocket.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Each automatic transfer switch shall be installed as shown on the Drawings and in accordance with the manufacturer's installation instructions.

B. The automatic transfer switch shall be provided with adequate lifting means for installation of wall or floor mounted enclosures.

C. The Contractor shall tighten all assembled bolted connections to the manufacturer's torque recommendations prior to energizing.

D. Install each switch to allow complete door swing required for component removal. This is specifically required where a switch is set next to a wall to the left of the switch enclosure.

3.02 RUBBER MATS

A. A three foot wide rubber mat shall be furnished and installed on the floor and in front of each indoor automatic transfer switch. The mat shall be long enough to cover the full length of each enclosure. The mat shall be 1/4 inch thick with beveled edges, canvas back, solid type with corrugations running the entire length of the mat. The mat shall be guaranteed extra quality, free from cracks, blow holes or other defects detrimental to their mechanical or electrical strength. The mat shall meet OSHA requirements and the requirements of ANSI/ASTM D 178 J6-7 for Type 2, Class 2 insulating matting.

END OF SECTION

SECTION 16500 - LIGHTING

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. The specific characteristics of the light fixtures to be furnished and installed shall be as detailed in the light fixture schedule on the Contract Drawings. Should a fixture of a different type or manufacturer than that specified be submitted for the Engineer's review, it will be compared to that specified on: construction, dimensions, and photometrics. Failure to compare equally to what was specified will be grounds for rejection.

B. The Contractor shall be prepared to submit sample equipment for appraisal when requested by the Engineer, and shall assume all transportation costs involved in the shipment and return of samples. All sample fixtures submitted shall be provided with lamps and shall be wired with cord and plug, to facilitate lighting for appraisal.

PART 2 - PRODUCTS

2.01 BALLASTS

A. All ballasts shall have built in thermal protection and be of the high power factor type built to conform to UL and ANSI standards (as attested by CBM certification).

B. Where shown on the Contract Drawings premium efficiency ballasts shall be provided with luminaires.

2.02 LUMINAIRES

A. All fixtures shall be delivered complete with suspension and mounting accessories, ballasts, drivers, diffusers, reflectors, etc., all wired and assembled. All accessory wiring shall be furnished and installed as shown on the Contract Drawings.

B. All steel supports required for luminaires in addition to that furnished under the general building construction shall be furnished and installed by the Contractor.

C. When fixtures are noted to be installed flush, they shall be complete with the proper accessories for installing in the particular ceiling involved. All flush mounted fixtures shall be supported from the structure and shall not be dependent on the hung ceilings for their support.

D. All outside luminaires shall be a type that will prevent insect accumulation inside the luminaire.

E. Exterior luminaires shall be weatherproof and rustproof.

F. Luminaires for vaults and pipe galleries shall be watertight and rustproof.

G. Luminaire wire shall be fixture type of non-asbestos construction.

H. Fixtures in hazardous environments shall be Listed for the area classification.

I. LED fixtures and parts shall comply with UL 8750.

2.03 LAMPS

A. Incandescent lamps shall be for 130 volt operation, unless otherwise specified.

B. Fluorescent lamps shall have standard cool white (CW) color characteristics unless otherwise indicated, and shall be of the type that will not require starter switches.

C. LED lamps shall comply with UL 8750 and California Energy Commission Minimum Specifications for California Quality LED Lamps CEC-400-2012-016-SF.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. General

1. The Contractor shall furnish all light fixtures, lighting equipment, components, hangers, etc., as shown on the Contract Drawings and shall install them at the locations shown on the Contract Drawings.

2. All fixture wiring shall be in conformance with the latest revision of the NEC and UL standards.

3. Lamps of the proper type, wattage and voltage rating shall be delivered to the project in the original cartons and installed in the fixtures just prior to the completion of the project, with spare lamps as listed on the Contract Drawings.

4. All incandescent and fluorescent lamps used during the building construction in contract lighting fixtures prior to 2 weeks from the completion of the work shall be removed and replaced with new lamps.

5. Locations of fixtures shall be coordinated with Engineer's reflected ceiling plans where they exist. Any conflicts between electrical plans and Engineer's reflected ceiling plans, the reflected plans shall override.

B. Luminaires

1. Fixtures shall be rigidly mounted against the surface of the ceiling unless otherwise noted on the Contract Drawings. Conduit runs to and between fixtures shall be rigid metallic type. Use of flexible conduit for connection to fixtures is prohibited, except where concealed above a suspended ceiling.

2. All ferrous metal surfaces of fixtures and plaster frames shall be treated and given rust-inhibiting and finish coat adherence properties before final enamel coats are applied. Finish enamel coat shall be baked on at approximately 320 degrees Fahrenheit.

3. Similar fixtures in each room or area shall be installed with bottom of fixtures at same elevation, unless otherwise noted.

4. Minimum wire size shall be AWG No. 10 for runs over 75 feet.

5. Outlets shall be as specified herein and shall be suitable for the installation conditions encountered.

6. Flexible fixture hangers shall be used for all pendant mounted fixtures.

7. Conduit run in areas with hung ceilings shall be installed in the space above the hung ceiling as close to the structure as possible. Conduits and junction boxes shall be supported from the structure.

8. No light fixtures shall be hung or installed until after painting is completed, however, temporary lighting shall be provided by the Contractor. Fixtures in suspended ceilings shall be fastened to the main tees of the ceiling grid.

9. All fixtures shall be left in a clean condition, free of dirt and defects, before acceptance by the Engineer.

END OF SECTION

16620 – PACKAGED ENGINE GENERATOR SYSTEMS

PART ONE - GENERAL

1.01 THE REQUIREMENT

A. The Equipment Supplier shall provide a standby power engine generator set(s) complete with fuel storage tank(s), leak detection systems, piping, exhaust silencer, batteries, charger, and other appurtenances as may be required for a TIER rating in force at the time of unit handover to owner.

B. It is the intent under this Contract to require a complete package in every detail whether or not specified. Consequently, the Equipment Supplier is responsible for all details, devices, accessories and special construction necessary to properly install, adjust, test, and place in successful operation the engine-generator set.

C. Use materials which are new, unused, and as specified, or, if not specifically indicated, the best and most suitable of their kinds for the purpose intended, and for the design and expected conditions of service, subject to the approval of the Engineer.

D. Provide workmanship that is first class in every respect. Employ workers thoroughly experienced in such work. A neat and workmanlike appearance in the finished work shall be required.

E. All materials used must bear the inspection labels of the Underwriter's Laboratories, if the material is of a class inspected by the Laboratory.

F. Unless otherwise indicated, the materials to be provided under this Specification shall be the products of manufacturers regularly engaged in the production of all such items and shall be the manufacturer's latest design. The products shall conform to the applicable standards of UL and NEMA, unless specified otherwise. International Electrotechnical Commission (IEC) standards are not recognized. Equipment designed, manufactured, and labeled in compliance with IEC standards is not acceptable.

G. The engine generator sets shall fully comply with all current Environmental Protection Agency (EPA) emission regulations for permanently-installed, diesel-fueled, emergency standby power. The engine generator set(s) must meet the EPA new source performance requirements required at the time the engine generator set(s) submittal is approved by the engineer. Engines manufactured previous to the submittal approval date that do not meet the current regulated emissions levels are not acceptable.

1.02 CODES AND STANDARDS

A. The packaged engine-generator system shall comply with the following Codes and Standards as a minimum:

1. NEMA MG1, Motors and Generators.

2. NEMA MG2, Safety Standard for Construction and Guide for Selection, Installation and Use of Motors and Generators.

3. ISO STD 8528, Reciprocating Internal Combustion Engines.

4. ISO STD 3046, Performance Standard for Reciprocating Internal Combustion Engines.

5. NFPA 30, Flammable and Combustible Liquids Code.

6. NFPA 70, National Electrical Code

7. NFPA 70E, Standard for Electrical Safety in the Workplace

8. NFPA 110, Standard for Emergency and Standby Power Systems.

9. UL 508, Industrial Control Equipment.

10. EGSA, Electrical Generating Systems Association.

11. UL 142, Steel Aboveground Tanks for Flammable and Combustible Liquids.

1.03 TESTING

A. All tests shall be performed in accordance with the requirements of the General Conditions. The following tests are required:

1. Witnessed Shop Tests

   a. None required.

2. Certified Shop Tests and Reports

   a. Fully test the engine-generator set with all accessories in the manufacturer's plant before shipment; test at various loadings from full load to no load, and at such other conditions as to properly establish that all requirements have been met. Tests shall be conducted through the use of balanced, three-phase, dry-type, resistive load banks. Obtain Engineer's approval before shipment is made.

   b. Submit two (2) certified copies of all test reports.

3. Field Tests

   a. Startup and field testing shall take place at the site of the Project.

   b. In the presence of the Owner's representative inspect, adjust and test the entire system and leave in good working order. Tests shall be conducted through the use of balanced, three-phase, dry-type, resistive load banks. Notify the Owner by letter approving the equipment as ready for test two (2) weeks prior to the running of the specified field test. Field tests shall be conducted after the entire system is completely installed. Field tests shall include, but are not limited to, the silencer, radiators, engine-generators, and all other equipment included in the complete system.

   c. Conduct a continuous test run of at least four (4) consecutive hours without shutdown for the set under the following conditions of load. If contractor takes exception to the load test it shall be indicated prior to submitting bids and documented as to an acceptable alternate testing.

      2 hours, full load
      1/2 hour, 3/4 load
      1/2 hour, 1/2 load
      1/2 hour, 1/4 load
      1/2 hour, no load

      Record complete test data for frequency, amperes, volts, power factor, exhaust temperature, coolant temperature, and oil pressure every 15 minutes during the continuous run test. If any failures and/or shutdowns occur during this four (4) hour test, the problems shall be fixed and the test shall be restarted. The test shall not be considered complete until the generator has operated for four (4) consecutive hours without any shutdowns under the conditions listed above.

1.04 SUBMITTALS

A. In accordance with the procedures and requirements set forth in the General Conditions the Equipment Supplier shall obtain from the equipment manufacturer and submit the following:

1. Shop Drawings
2. Spare Parts List
3. Special Tools List
4. Reports of Certified Shop and Field Tests
5. Operation and Maintenance Manuals

B. Each submittal shall be identified by the applicable Specification section.

1.05 SHOP DRAWINGS

A. Each submittal shall be complete in all respects, incorporating all information and data listed herein and all additional information required for evaluation of the proposed equipment's compliance with the Contract Documents.

B. Partial, incomplete or illegible submittals will be returned to the Equipment Supplier without review for resubmittal.

C. Shop drawings for <u>each engine-generator set</u> shall include but not be limited to:

1. A Compliance, Deviations, and Exceptions (CD&E) letter. If the shop drawings are submitted without this CD&E letter, the submittal will be rejected. The letter shall include all comments, deviations and exceptions taken to the Specifications by the Equipment Supplier AND Equipment Manufacturer. This letter shall include a copy of this specification section. In the left margin beside each and every paragraph/item, a letter “C”, “D”, or “E” shall be typed or written in. The letter “C” shall be for full compliance with the requirement. The letter “D” shall be for a deviation from the requirement. The letter “E” shall be for taking exception to a requirement. Any requirements with the letter “D” or “E” beside them shall be provided with a full typewritten explanation of the deviation/exception. Handwritten explanation of the deviations/exceptions is not acceptable.

2. Standard manufacturers printed specification sheet showing critical engine and generator set specifications including the following:
   a. Dimensions, and weights
   b. Guaranteed fuel consumption at 25%, 50%, 75% and 100% of full rated load
   c. Engine bhp available
   d. Engine jacket water heat rejection
   e. Exhaust flow rate and temperature at 100% of rated load
   f. Ventilation and combustion air requirements
   g. Exhaust backpressure limitation
   h. Liquid refill capacities
   i. Generator efficiency at 50%, 75%, and 100% load
   j. Telephone Interference Factor (TIF)
   k. Harmonic waveform distortion
   l. Type of winding insulation and generator temperature rise
   m. Voltage regulation characteristics
   n. Guaranteed noise levels
   o. Per unit subtransient impedance X’’ and X/R ratios for positive, negative, and zero sequences
   p. Transient reactance (Xd’)

q. Synchronous reactance (Xd)
r. Sub transient time constant (Td'')
s. Transient time constant (Td)
t. DC time constant (Tdc)
u. Decrement curve

3. Engine and generator material composition and construction.

4. Manufacturer's printed warranty statement of the engine and generator set showing single source responsibility by the engine manufacturer.

5. Generator control panel equipment and features. Include a written explanation of the auto start/stop logic and operation.

6. Engine-generator set and accessory catalog data sheets including, but not limited to, the vibration isolators, flexible exhaust coupling, exhaust silencer, batteries, battery charger, main line circuit breaker and enclosure, circuit breaker trip units, fuel lines, fuel level devices, jacket coolant heater, generator strip heater, fuel tank(s) and pump(s).

7. Standard dealer preventative maintenance contract for review and possible adoption under a separate Contract. Dealer must have existing contracts and personnel and contractual detailed performance information available.

8. Normal operating ranges for systems temperature, pressure and speed.

9. Manufacturer's part number for the engine and generator operation guide, parts book, service manual, warranty policy, and installation guide.

10. Phone numbers of twenty-four (24) hour products support contacts and locations.

11. Drawing showing right hand, left hand, and top views of proposed assembly; battery rack, isolators, exhaust silencer, conduit stub up locations, and flexible fittings; wiring schematics, interconnection diagrams (point to point), and written description of engine generator controls and alarm circuits.

12. Control panel layout drawings and wiring diagrams.

13. Drawings and specifications for base-mounted fuel storage tank with accessories and leak detection system.

14. Detailed drawings showing plan, front, and side views as well as appropriate section views of the weatherproof, engine-generator enclosure. Include product data sheets for all appurtenances (e.g. exhaust fan, thermostat, lighting, switches, receptacles, combination power unit, etc.) to be furnished and installed in the enclosure.

D. The shop drawing information shall be complete and organized in such a way that the Engineer can determine if the requirements of these Specifications are being met. Copies of technical bulletins, technical data sheets from "soft-cover" catalogs, and similar information which is "highlighted" or somehow identifies the specific equipment items the Equipment Supplier intends to provide are acceptable and shall be submitted.

1.06 OPERATION AND MAINTENANCE MANUALS

A. The Equipment Supplier shall submit operation and maintenance manuals in accordance with the procedures and requirements set forth in the General Conditions.

B. Furnish identical bound instruction manuals covering operating procedures, lubrication, and maintenance requirements of all equipment furnished under this Item. Include wiring diagrams, drawings, product data sheets, parts lists, and other necessary data. Number or otherwise

clearly identify all parts to facilitate ordering of replacements. Exclude data not pertinent to this installation. Within manual, fill in serial number, model number, and nameplate data of engine and generator provided.

1.07 TOOLS, SUPPLIES, AND SPARE PARTS

A. The engine-generator systems shall be furnished with all special tools necessary to disassemble, service, repair and adjust the equipment as part of a regular maintenance program. All spare parts as recommended by the equipment manufacturer shall be furnished to the Owner by the Equipment Supplier.

B. The Equipment Supplier shall furnish the following spare parts for each engine-generator set:

No. Required	Description
1	Set of Fuel Oil Filters
1	Set of Air Filters
1	Set of Lube Oil Filters
1	Set of Fuel Oil/Water Separator Filters

C. The spare parts shall be packed in containers suitable for long term storage, bearing labels clearly designating the contents and the pieces of equipment for which they are intended.

D. Spare parts shall be delivered at the same time as the equipment to which they pertain. The Equipment Supplier shall properly store and safeguard such spare parts until completion of the work, at which time they shall be delivered to the Owner.

E. Spare parts list, included with the shop drawing submittal, shall indicate specific sizes, quantities, and part numbers of the items to be furnished. Terms such as "1 lot of packing material" are not acceptable.

F. The dealer shall have sufficient parts inventory to maintain over-the-counter availability of at least 90% of any required part and 100% availability within 48 hours.

1.08 SERVICE OF MANUFACTURER'S REPRESENTATIVE

A. The Equipment Supplier shall provide the services of a qualified manufacturer's factory-trained technical representative to provide training as specified.

B. The engine-generator set manufacturer shall have an authorized dealer within 100 miles radius who can provide factory trained service, the required stock of replacement parts, technical assistance, and warranty administration for all components supplied by the dealer.

1.09 IDENTIFICATION

A. Each engine-generator set shall be identified with the identification number specified by the Owner. A nameplate shall be securely affixed in a conspicuous place on the generator.

1.10 TRAINING

A. The Equipment Supplier shall provide training for Owner personnel. Training shall be conducted by the manufacturer's factory trained specialists who shall instruct Owner personnel in operation and maintenance of all equipment provided under this Section.

B. Training for the generator shall be performed at the Project site for two (2) days, eight (8) person hours each day for a total of sixteen (16) person hours of training.

C. Each generator shall be tested on pump station load for a minimum of 30 minutes during field training.

1.11 WARRANTY TERMS

A. The manufacturer's and dealer's standard warranty shall in no event be for a period of less than two (2) years or four hundred (400) hours of operation, whichever comes first, from date of initial start-up of the system and shall include repair labor, travel expense necessary for repairs at the jobsite, and expendables (lubricating oil, filters, antifreeze, and other service items made unusable by the defect) used during the course of repair. Submittals received without written warranties as specified shall be rejected in their entirety.

PART TWO -- PRODUCTS

2.01 MANUFACTURERS

A. The equipment covered by this Specification is intended to be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, constructed and installed in accordance with the best practices of the trade, and shall operate satisfactorily.

B. Consideration will be given only to the equipment of those manufacturers who have furnished comparable size diesel engine-generator sets for at least two similar installations that have been in regular successful operation for not less than five (5) years.

C. The Equipment Supplier shall furnish evidence of this experience and data on the equipment's operation at these installations to the Engineer upon request.

D. The engine-generator set manufacturer shall be responsible for the entire engine-generator package including the engine-generator set with enclosure, fuel system, piping, accessories, electrical equipment, and other devices for a complete and operable system. The engine-generator set manufacturers shall be:
   1. Cummins/ONAN
   2. Caterpillar
   3. Engineer-approved equal

2.02 GENERAL DESCRIPTION

A. The engine-generator set(s) shall be rated 2,500 kW, 3,125 sKVA, 4,160/2400-volt, WYE with low resistance neutral ground and ground fault monitoring equipment, 3-phase, 0.8 P.F. emergency standby power. Provide complete resistor and monitoring system with generator properly sized and settings for system configuration.

   It shall have the capability to operate at its standby rating for the duration of any power outage with all accessories including engine running devices, silencer, radiator, cooling fans, fuel system, and all appurtenances installed. The kW capacity above is based on loads and sequencing defined in generator sizing software limiting the voltage drop and frequency drop to a maximum of 20% and 5% respectively. The engine-generator running kW and starting kVA capacity shall not be less than that stated above. Only manufacturer’s standard ratings shall be acceptable. No dealer special ratings will be acceptable.

2.03 ENGINE

A. The engine shall be diesel, 4 cycle, radiator cooled, and shall be turbocharged having an operating speed of 1800 RPM. Engine shall operate on No. 2 diesel fuel. Engines requiring premium fuels are not acceptable.

B. The specified standby kW rating shall be for continuous electrical service during interruption of the normal utility source, per NEMA standards. Prime rating shall also be included in the submittal where available.

C. Engine speeds shall be governed by an electronic isochronous governor that will sense generator speed and provide accurate load transient correction capability at less than 0.5 percent regulation, from no load to full load generator output.

D. The engine shall have a 12 or 24 volt battery charging generator with an automatic charge rate regulator. Starting shall be by a 12 or 24 volt electric starter.

2.04 GENERATOR

A. The generator shall conform with NEMA and IEEE standards. The generator shall be brushless, salient pole, 2/3 pole pitch and synchronous.

B. Laminations and windings shall be designed for minimum reactance, low voltage waveform distortion and maximum efficiency.

C. Insulation shall be Class H, 125 degrees C rise according to NEMA standards. All windings and coils shall have an additional treatment of three (3) coats of varnish to prevent fungus growth.

D. Radio interference suppression (both directions) shall be provided in accordance with NEMA and IEEE Standards.

E. The alternator shall have a brushless, permanent magnet exciter. The exciter shall supply field excitation to maintain output with the alternator loaded to 300% of continuous rating for 10 seconds at rated power factor.

F. Waveform deviation shall not exceed 5% from true sine wave. The transient response from no load to full load in one step of the engine-generator set shall not exceed a voltage dip of 35%, a frequency dip of 20%, and shall recover to complete steady state performance within 12 seconds for both voltage and frequency. The transient response from full load to no load in one step shall not exceed a voltage overshoot of 7% and shall recover to steady state performance within 3 seconds.

G. The Telephone Influence Factor (TIF) shall be less than 50.

H. The voltage regulator shall be an adjustable, solid-state, three-phase RMS sensing, volts/hertz type. Voltage regulation shall be a minimum of +/-0.5% from no load to continuous rating. The voltage regulator shall provide +/-10% voltage adjustment. The voltage regulator shall be located within the engine control panel.

I. A 120VAC generator mounted strip heater shall be furnished and installed as part of the system. The strip heater shall be "ON" to prevent condensation when the engine generator set is not running.

2.05 CONTROLS

A. Engine-generator monitoring and controls shall be mounted in a single NEMA 1 dust-tight enclosure. A suitable accessible terminal strip having all wires properly identified shall be furnished. The panel shall include a local engine failure alarm, a dry contact for remote "Generator System Failure" alarm indication, and engine starting control wire. The panel shall be mounted between 5’-0” and 6’-0” measured from the center of the panel to ground level. Elevated platform and handrail may be required, as determined by Owner, for control panels exceeding 6’-0”.

B. The engine starting shall be automatic and shall include a starting motor, a cranking contactor, provisions for electrically operated fuel control, and protective devices for low oil pressure, high coolant temperature, low coolant level, and overspeed conditions.

C. The automatic engine starting control shall operate from a single pole contact which closes for engine run and opens for engine stop. When the engine starts, starting control shall automatically disconnect cranking controls.

D. The cranking disconnect means shall be electrically self-regulating to prevent recranking for a definite time after source voltage has been reduced to a low value. If the engine fails to fire, or any safety device should operate while the engine is running, the engine shall be stopped immediately and the starting controls locked out requiring manual resetting.

Failure to start shall initiate an alarm signal that must be reset in order to have the alarm activated after normal power is restored. The "Failure to Start" signal shall be derived from a dry contact closure which is wired as part of a common "Generator System Failure" alarm.

E. Starting control circuits shall be arranged so that cranking will commence immediately after the single pole contact closes. Four cranking cycles of 10 seconds "ON", 10 seconds "OFF" shall be provided.

F. The automatic engine starting controls shall use industrial rated control type elements throughout, and controls shall have the capability to operate at 50% battery voltage. Indicating lamps, pushbuttons, selector switches, and other pilot devices shall be accessible and mounted on the control enclosure.

G. A molded case generator/exciter field circuit breaker shall be furnished and installed as part of the engine generator set.

H. Molded case main line circuit breaker(s) as specified herein shall be installed as load circuit interrupting and protection devices in NEMA 1 (gasketed) dust-tight enclosures. They shall operate both manually for normal operation and automatically for protection against overload or short circuits. Generator/exciter field circuit breakers are not acceptable for this service.

The molded case circuit-breakers described above shall be manufactured and tested in accordance with U.L. and NEMA AB1 standards. Their interrupting rating shall be suitable for the available fault current. All electrical ratings shall be suitable for the application.

I. The devices necessary for automatic starting shall be on the engine and in the engine control panel.

J. Engine-generator monitoring and control shall be provided using a microprocessor based control panel (EMCP 3.3, Digital Control Panel, Power Command, or equal) complete with LCD displays. All monitoring and control signals shall communicate with the Automatic Transfer Switch through Modbus TCP/IP communication protocol. Refer to specification section 18100, I/O list for details. Engine-generator monitoring and control shall include, but not be limited to, the following:

1. Engine oil pressure indicator
2. Coolant temperature indicator
3. Voltmeter
4. Ammeter
5. Phase selector switch
6. Running time meter
7. Frequency meter
8. High coolant temperature shutdown, signal light
9. Low oil pressure shutdown, signal light
10. Low oil level, signal light
11. Engine overspeed shutdown, signal light

12. Engine overcranking protection with signal light (after a cranking cycle of one minute, engine cranking shall stop)
13. Engine tried to start but failed signal light
14. Low coolant level signal light
15. Engine "Run" (green) and "Fail"signal lights
16. Low coolant temperature signal light
17. Pre-high engine temperature indication
18. Pre-low fuel indication
19. Low fuel shutdown indication
20. Fuel leak indication
21. Engine Failure alarm, dray contact for alarm output
22. Generator System Failure, dry contact for alarm output
23. Engine start input relay
24. Low battery indication.
25. Battery charger fail indication
26. Engine control mode switch (Run-Off-Auto)
27. Tachometer and engine speed (RPM) indicator
28. Emergency stop pushbutton
29. Generator voltage adjust potentiometer
30. Generator frequency adjust potentiometer
31. Indicator/display test switch
32. Panel lights with On/Off switch
33. Modbus TCP/IP Communication and 120V dry contacts shall be available for indicating the following to Owner's SCADA system Via Automatic Transfer Switch.
    a. Generator running.
    b. Generator Run-Off-Auto control switch in "Auto".
    c. Generator pre-shutdown alarm.
    d. Generator shutdown alarm.

2.06 ENGINE ACCESSORIES

A. Furnish and install the engine with all accessory equipment and appurtenances which may be required for proper operation, including the following:

1. Dry type air cleaner
2. Engine driven lubricating oil pump
3. Lubricating oil strainer
4. Lubricating oil filter, bypass type, with replaceable absorbent-type elements
5. Lubricating oil cooler, water cooled
6. Lubricating oil cooling circulator pump (may be integral with main oil pump)
7. Fuel oil transfer pump
8. Fuel oil strainer
9. Fuel oil filter, with replaceable absorbent-type elements
10. Fuel oil fuel/water separator
11. Electronic controlled fuel injection
12. Fuel oil injection valve assemblies
13. Electronic isochronous governor
14. Radiator and cooling fan
15. Jacket water circulating pump
16. Thermostats
17. Water expansion tank
18. Exhaust manifold
19. Automatic battery starting system
20. Cold starting aid engine block heaters with all controls
21. Radiator mounted fuel cooler to cool recirculated fuel before it is re-deposited into the fuel tank as recommended by the manufacturer.

2.07 MOUNTING

A. Couple the engine and generator together through a flexible, non-backlash type, all metal coupling which overcomes all normal misalignment stresses and transmits full engine torque with ample safety factor. Also provide flexible connections for piping connections.

2.08 RADIATOR

A. Provide a radiator manufactured of a non-corrosive material mounted on the engine. The radiator core shall be coated with a corrosion resistant coating. Corrosion resistant coating shall be a corrosion resistant baked phenolic coating or similar.

B. Connect the radiator to the engine internal cooling system with flexible piping.

C. The engine shall be cooled through a radiator sized to continuously maintain safe operation at full load and at 105°F outside ambient air with 50% ethylene glycol coolant. A blower type fan and low noise fan drive and controls shall be furnished. The fan and all rotating members and drive belts shall be guarded and meet OSHA standards.

D. The unit shall be provided with 50% ethylene glycol. Nalcool treatment shall also be added to the system in the proper proportion.

E. Unit mounted thermal circulation type water heaters shall be furnished to maintain engine jacket water temperature as recommended by manufacturer in an ambient temperature of 10° F. The heaters shall be single phase, 60 hertz, 120 volt or 240 volt AC thermostatically controlled.

2.09 ENGINE STARTING SYSTEM

A. Provide an engine starting system complete with battery charger and batteries.

B. The charger shall be an automatic battery charger, 10 A max, current limited, ±2% voltage regulation, ±10% line voltage variation, equalizing timer, DC voltmeter, and DC ammeter. Provide a 0-24 hour equalize timer and a Form C Dry Contact to indicate a low battery alarm condition.

C. Starting batteries shall be NICAD 24 volts having adequate capacity for rolling the engine for five (5), ten (10) second cycles without starting and operating the control devices in the generator panel. The batteries shall be mounted on a suitable non-corrosive rack. Batteries shall have battery cables with lugs and shall be provided with lugs for connection to the battery charger.

2.10 EXHAUST SILENCER

A. Furnish and install an exhaust silencer mounted within the generator building. The silencer system shall be designed, furnished, and installed to prevent moisture and condensation from corroding the silencer. Silencers shall be insulated using a calcium silicate material covered by a brushed aluminum skin. All exterior components of the exhaust silencer system shall be of 316 stainless steel. The work shall result in a long-term, aesthetically pleasing installation.

B. Inlet and Exhaust Systems: Silencers and exhaust ducting to silencers shall be self-supporting when assembled. Provide all necessary supporting members for ductwork between silencer and outlet. Provide all required cutting as shown on Drawings and noted herein. The unit shall be complete with raincap. All exhaust ducts shall be Schedule 10 304 stainless steel pipe minimum. Inlet silencer and filter to be self-supporting. Provide necessary supports for all intake ductwork. All intake ducts shall be Schedule 10 steel pipe minimum.

1. Provide bellows sections, insulated wall thimbles, and inlet and outlet flexible section as shown on Drawings. Design of exhaust silencer and stack including all ducting shall have a pressure drop not exceeding 5 inches of water.
2. Provide a silencer which meets sound standards of a critical area. Silencer shall provide attenuation (input to output) of 39 dB or greater at frequencies of 125 hertz to 8 kilohertz.

A curve shall be submitted with Shop Drawings showing attenuation (input to output) in dB versus frequency. Curve shall be on manufacturer's standard data sheet or from an independent test lab. The silencer shall be a slim line space saving design equal to GT EXHAUST Model 501-C2-6100. The silencer shall comprise of a 2 inch compressed thermal/acoustical fiberglass packed shell. The overall silencer height shall be limited to 15 inches and overall length of 65 inches. A spiral or bellows-type flexible section of pipe shall be installed in the exhaust line between the muffler and engine manifold connection. An insulated thimble section shall be provided where exhaust line passes through roof or wall. Exhaust lines shall be pitched and a condensation trap provided at nondraining low points in line.

C. Connect the silencer to the engine exhaust manifold with a high corrosion and temperature resistant stainless steel flexible convoluted exhaust pipe. Use flange-type connections. Provide a taper-cut tail pipe complete with rain cap to exhaust the gases to the atmosphere.

D. The exhaust manifold, exhaust piping, and expansion fittings including collector box, shall be completely covered with an insulation blanket in order to protect operating personnel and to reduce noise. Insulation shall be of composite fiberglass and stainless steel construction capable of withstanding 1,200°F continuously. The insulation blankets shall be tailored and custom fabricated to fit the contours of the manifolds.

2.11 FUEL TANK

A. The generator set shall be supplied with a U.L.-142 listed, double-walled, outdoor fuel tank of sufficient capacity to operate the engine-generator set at full load for a minimum of 72 hours at full load. The tank, painted in a color as selected by the Engineer, shall be fabricated from steel with a rupture basin and leak detector system. The alarm and indicator for the leak detection shall be mounted adjacent to the generator control panel.

B. A level device shall also be furnished and installed to provide a local (generator control panel) indication of pre-low fuel tank level and low fuel tank level. The low fuel tank level alarm shall shut down the engine to prevent the fuel level from dropping below the fuel pickup piping in the fuel tank. The pre-low fuel level alarm shall activate when only 6 hours of fuel for full load operation remains in the fuel tank.

C. The tank shall be supplied with all necessary fuel supply, return, vent, and fill fittings and a fuel level gauge. The lockable fill port and level gauge shall be easily accessible from outside the enclosure. The vent line shall be piped to the outside and be equipped with a fill whistle.

D. The system shall be equipped with a radiator mounted fuel cooler, which shall remove all heat added to fuel in the recirculation process at a 105°F ambient.

E. A day tank with pumps, alarms, level indicators, Pryco “Standard” unit 120 volt, 1 pH, 60 HZ, double wall.

F. Piping shall be cleaned and painted black with oil based enamel.

G. Provide underground fuel pipe containment and leak detection with alarms and dry contacts for PLC monitoring.

2.12 WEATHERPROOF ENGINE - GENERATOR ENCLOSURE

A. Unit will be located in a building; no enclosure required.

PART 3 -- EXECUTION

3.01 INSTALLATION

A. After successful completion of all field testing and immediately prior to final inspection, the Equipment Supplier shall fill the fuel tank(s) and all other fluid levels to their capacity for the standby power system.

B. The Equipment Supplier shall be responsible for delivering the generator sets to the Owner after all testing and engine startup.

END OF SECTION

SECTION 16670 - LIGHTNING PROTECTION SYSTEMS (AIR TERMINALS)

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. The lightning protection system shall be furnished, installed, and connected as detailed on the Contract Drawings to provide a complete and functional system. Installation and equipment construction shall comply with Lightning Protection Institute Installation Code LPI-175, UL Master Label Code 96A, and NFPA 780.

B. The Contractor shall provide shop drawings indicating location and installation of equipment for review of the Engineer before beginning installation.

C. All equipment shall be of the same manufacturer, insofar as possible.

D. Equipment specified herein supplements actual suppression devices specified in Section 16280.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. “Thompson Lightning Protection, Inc.,” “Independent Protection Co., Inc.,” or equal.

2.02 EQUIPMENT

A. All equipment used in this installation shall be UL approved and labeled in accordance with UL procedures, with each air terminal bearing an “A” label and all main conductors bearing a “B” label at 10'-0" intervals.

B. All equipment shall be new, and of design and construction to suit the application where it is used in accordance with accepted industry standards and LPI and UL code requirements and as per manufacturers recommendations.

C. Downlead conductors from roof to ground shall be copper, of 28 strands, 17 gauge minimum. All main roof conductors shall be aluminum, of 24 strands, 14 gauge minimum.

D. Air terminals shall be solid, round aluminum bar of 1/2” minimum diameter, and shall project 10" minimum above the object to be protected.

E. Air terminal bases shall be of cast aluminum with bolted pressure cable connections and shall be securely mounted with stainless steel screws or bolts. Bases on built-up tar and gravel roofs shall be secured with a proper adhesive and shall have a minimum surface contact area of 18.5 square inches.

F. Ground rods shall be a minimum of 3/4" in diameter and 10'-0" long. They shall be connected to the system using exothermic welds, Cadweld, or equal.

G. Cable fasteners shall be substantial in construction, electrolytically compatible with the conductor and mounting surface and shall be spaced according to LPI and UL code requirements.

H. Bonding devices, cable splicers and miscellaneous connectors shall be of cast aluminum with bolted pressure connections to cable. Cast or stamped crip fittings are not acceptable.

I. Equipment on stacks and chimneys shall be protected from corrosion and sized in

accordance with LPI and UL requirements.

J. All miscellaneous bolts, nuts, and screws shall be stainless steel.

K. An approved bimetal transition fitting shall be used at the roof level to change from aluminum roof conductor to copper downlead cable.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

A. The installation shall be accomplished by an experienced installer listed with Underwriters' Laboratories as qualified and who is also a Certified Master Installer of the LPI or working under the direct supervision of an LPI manufacturer as listed above or his authorized LPI Certified Master Installer representative.

B. All equipment shall be installed in a neat workmanlike manner in the most inconspicuous manner possible. The system shall consist of a complete cable network on the roof including all air terminals, splices, and bonds with cable downleads routed concealed either directly in the building construction for a new structure or in conduit to ground for an existing structure.

C. The copper downlead cables shall not be brought directly through the roof. Through roof connectors with solid rods or conduits though pitch pockets shall be utilized for this purpose.

D. The limitations on areas of usage for aluminum cables and for copper and aluminum materials together as outlined in UL 96A and LPI 175 shall be observed. The lightning protection installer will work with other trades to ensure a correct, neat, and unobtrusive installation.

E. It shall be the responsibility of the lightning protection installer to assure a sound bond to the metallic main water service and to assure interconnection with other building ground systems, including both telephone and electrical and also to ensure that proper arresters have been installed on the power service.

F. Downlead conductors from roof to ground shall be protected from mechanical damage from a point 8 feet above to 1 foot below grade by conduit or other means.

G. The lightning protection installer shall secure and deliver a UL Master Label and LPI System Certification to the Engineer for the Owner upon completion of the installation.

H. The Contractor shall also submit 2 copies of as built shop drawings, 1 with the UL Master Label Application Form and another with LPI forms 175A and B.

I. A permanent plate shall be affixed to the protected structure in a prominent location, indicating its UL approval.

END OF SECTION

SECTION 16710 - COMMUNICATION SYSTEMS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. This Section of the specifications addresses Contractor's requirements for communication systems. The work includes raceways, cables, runways, entrance facilities, cabling, labor and equipment to execute communication systems as detailed on the Drawings.

B. The Contractor is responsible for furnishing and installing all raceway and cables with 14 feet of slack at terminals and cabinets.

C. The structured telecommunications cable and pathway distribution and wiring system shall include permanently installed horizontal cabling, horizontal pathways, telecommunications outlet assemblies, conduit, raceway, and hardware for splicing, terminating, and interconnecting. The horizontal system includes the cabling and pathway between the PLC cabinets. Hardware and terminating equipment shall consist of UL approved, 110 RJ-45 connectors. Horizontal cable shall consist of Category 6 (1,000 MPBS) 100 ohm four (4) pair cable, unshielded twisted pair (UTP).

D. Use shielded cables inside VFD cabinets.

E. Use multi-mode FO cable for interface with existing plant SCADA.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Drawings and General Provisions of this Contract including General and Supplementary Conditions and Division 1 Specifications Sections, apply to work of this Section.

B. Related Work in Other Technical Sections

1. Section 16050 - Basic Electrical Materials and Methods

2. Section 16120 - Wire and Cables

3. Section 16130 - Raceways

4. Section 16131 - Boxes

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Telephone and Data Cables: Belden, or approved equal.

B. FO Cables: Optical Cable Corp.

2.02 MATERIALS

A. Components

1. Cabling passages shall be accessible via junction boxes and equipment cabinets. All cable installation will be facilitated with pull wires. Fixed cables and pathway systems for telecommunications systems shall be UL listed or third party independent testing laboratory certified, and shall comply with NFPA 70.

B. Pathways (Horizontal)

1. EIA/TIA-569 Pathway shall be conduit. Provide grounding and bonding as required by EIA/TIA-607. Provide Mogul style pulling elbows (See section 16130,3.02,27).

C. Telecommunications Cabling

1. Cabling shall be UL listed for the application and shall comply with TIA-568 and ANSI/TIA/EIA-568-B.2-1 and NFPA 70. Cabling shall consist of Category 6 (1,000 MBPS) UTP cable. Provide a labeling system for cabling as required by EIA/TIA 606 and UL 969. Cabling manufactured more than 12 months prior to date of installation shall not be used.

D. Telecommunications Outlet/Connector Assemblies

1. Jacks shall comply with FCC Part 68.5, and TIA/EIA-568. Jacks shall accommodate UTP. UTP jacks shall be RJ-45 designation T568A type, UL 1863 listed, eight position, constructed of high impact rated thermoplastic housing rated for Category 6 (1,000 MBPS) service. UTP jacks for data shall be Category 6 (1,000 MBPS) hardware and shall comply with the attenuation requirements contained in ANSI/TIA-568-B.2-1. Telecommunications cover plates shall comply with UL 514C, and TIA/EIA-568.

E. Fiber Optic Cable

1. The fiber optic cable shall be a round, water-resistant, tight buffer cable suitable for both indoor and outdoor installation. The fiber optic cable shall consist of, but not be limited to the following components:

   a. Multimode, helically arranged, optical fibers with Aramid strength member and 900 micro meter tight buffer

   b. Elastomeric subcable jacket to prevent moisture intrusion

   c. A synthetic yarn strength member helically laid directly over the stranded core

   d. PVC core-locked outer jacket

2. Each optical fiber shall be all glass, graded index, with a core diameter of 62.5 microns and cladding diameter of 125 microns. The optical fiber shall have an attenuation no greater than 3.0dB/km at a wavelength of 850nm supporting a bandwidth of no less than 220MHz-km. The fiberglass shall be manufactured by AT&T, or equal.

3. The minimum bend radius of the cable under full long-term tensile load shall be no longer than 10-times the outside diameter of the cable. The outer jacket of the cable shall be surface printed with the manufacturer's identification, the cable part number and sequential numerical footmarks.

4. The cable manufacturer shall be ISO 9001 certified, UL listed and optimized for Gigabit Ethernet applications. Gell-filled cables are not acceptable. The cable shall be manufactured by Optical Cable Corp., B Series Ultra-Fox Plus Breakout Cables (fiber part no. W3RB/1GC), or equal.

F. Fiber optic waterproof termination shall be of ST all polymer type (including body and ferrule) as manufactured by Methode Electronics, Inc. Termination fiber must be bonded within the ST connector ferrule utilizing two part anaerobic bonding compound. Crimp type connectors and/or epoxy heat cure connectors that require ovens shall not be deemed acceptable. The fiber optic ST connector shall be the 908 Series MST Style by Methode Electronics, Inc. Upon proper termination of the fiber optic cabling, the Contractor shall measure dB losses

over the cable length using an Engineer approved fiber testing device. This device shall be capable of producing hard copy test results for submittal to the Engineer. Official fiber tests are to be witnessed by the Engineer. In addition to allowing 1dB loss per connector, losses exceeding 3dB per kilometer of fiber will not be acceptable. All fiber technicians must be trained and certified by the fiber connector manufacturer. All connections must be approved by the fiber connector manufacturer. SC Connectors may be used as well.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION

A. Telecommunications cabling and pathway systems, including the horizontal cabling and pathway systems, telecommunications outlet/connector assemblies, and associated hardware shall be installed in raceway in accordance with TIA/EIA-568, EIA/TIA-569, NFPA 70, and UL standards as applicable.

B. Cabling

1. Install Category 6 (1,000 MBPS) UTP, telecommunications cabling and pathway system as detailed in TIA/EIA-568. Each RJ-45 connector shall have run to it one dedicating cable containing four pairs. Cabling installation shall comply with EIA TSB4O and EIA TSB-36. Screw terminals shall not be used except where specifically indicated on drawings. Use an approved insulation displacement connection (IDC) tool kit for copper cable terminations. Do not untwist Category 6 (1,000 MBPS) UTP cables more than 12 mm (one half inch) from the point of termination. Provide service loop on each end of the cable (one meter) for future additions. Do not exceed manufacturers' cable pull tensions for copper cables. Provide a device to monitor cable pull tensions. Do not exceed 110 N(25 pounds) pull tension for four pair copper cables. Do not chafe or damage outer jacket materials. Use only lubricants approved by cable manufacturer. Do not over cinch cables, or crush cables with staples.

C. Pathway Installations

1. Comply with EIA/TIA-569. Keep conduit minimum 150 mm (6-inches) away from parallel runs of electrical power equipment, flues, steam, and hot water pipes. Install conduit parallel with or at right angles to ceilings, walls, and structural members where located above accessible ceilings and where conduit is visible after completion of project. Install no more than two 1.57 rad (90 degree) bends for a single horizontal cable run.

2. All wiring shall be installed in conduit or a metal raceway. 3/4-inch minimum conduit size.

3. To facilitate future cable installations, a new pull string shall be pulled in conduit simultaneously with cables being installed.

4. All communication junction boxes shall be marked "DATA" or painted green.

3.02 TESTING

A. Telecommunications Cabling Field Testing

1. Perform telecommunications cabling inspection, verification, and performance tests in accordance with TIA/EIA-568.

B. Inspection

1. Visually inspect cabling jacket materials for UL or third party certification markings. Visually inspect UTP and OFO jacket materials for UL or other certification markings. Inspect cabling terminations in telecommunications rooms and at workstations to confirm

color code for tip and ring pin assignments, and inspect cabling connections to confirm compliance with TIA/EIA-568. Visually confirm Category 6 (1,000 MBPS) marking of outlets, wallplates and jacks.

C. UTP Verification Tests

1. UTP copper cabling shall be tested for DC loop resistance, shorts, opens, intermittent faults, near-end cross talk, proper pinning and termination and polarity between conductors. Test operation of shorting bars in connection blocks. Perform 250 MHz near-end cross talk (NEXT), far-end cross talk (FEXT) return loss, propagation delay, delay skew requirements, and attenuation tests for Category 6 (1,000 MBPS) 100 ohm 4-pair systems installations.

D. FO Cable Verification Tests

1. Contractor's Field Test: The Contractor shall verify the complete operation of the data transmission system in conjunction with field testing associated with systems supported by the fiber optic data transmission system prior to formal acceptance testing. Field tests shall include a flux density test. These tests shall be performed on each link and repeated from the opposite end of each link.

2. Optical Time Domain Reflectometer Tests: Optical time domain reflectometer tests shall be performed using the FO test procedures of EIA 455-59. An optical time domain reflectometer test shall be performed on all fibers of the FO cable on the reel prior to installation. The optical time domain reflectometer shall be calibrated to show anomalies of 0.2 dB as a minimum. An optical time domain reflectometer test shall be performed on all fibers of the FO cable after it is installed. The optical time domain reflectometer shall be calibrated to show anomalies of 0.2 dB as a minimum. If the optical time domain reflectometer test results show anomalies greater than 1 dB, the FO cable segment is unacceptable. The unsatisfactory segments of cable shall be replaced with a new segment of cable. The new segment of cable shall then be tested to demonstrate acceptability.

3. Power Attenuation Test: Power attenuation test shall be performed at the light wavelength of the transmitter to be used on the circuit being tested. The flux shall be measured at the FO receiver end and shall be compared to the flux injected at the transmitter end. There shall be a jumper added at each end of the circuit under test so that end connector loss shall be validated. Rotational optimization of the connectors will not be permitted. If the circuit loss exceeds the calculated circuit loss by more than 2 dB, the circuit is unsatisfactory and shall be examined to determine the problem. The Engineer shall be notified of the problem and what procedures the Contractor proposes to eliminate the problem. The Contractor shall prepare and submit a report documenting the results of the test.

4. Gain Margin Test: The Contractor shall test and verify that each circuit has a gain margin which exceeds the circuit loss by at least 6 dB.

END OF SECTION

SECTION 16900 - CONTROLS

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Equipment controls shall be as specified herein and shown on the Contract Drawings. Legends for starter nameplates shall be taken from the one line diagram in the Contract Drawings.

B. Certain equipment starters contain nonresettable elapsed time meters as shown in the Contract Drawings. Also, certain motor starters have remote control devices and require connections to operate these control devices as shown on starter schematics (control circuits).

C. All starters contain red “on” lights, control transformers, and auxiliary contacts to operate as defined on the control circuits of the Contract Drawings. Reset pushbuttons shall also be provided for overloads built into the starters.

1.02 CUSTOM CONTROL PANELS

A. All control panels furnished under this Contract shall be manufactured in accordance with industry standards and as herein specified. Some control panels are specified to be furnished with the equipment controlled and others are to be furnished by the Contractor, as written elsewhere.

B. Panel construction shall comply with OSHA and other code requirements as applicable, and may be attested to by UL listing the panels as an assembly. Otherwise, panel modifications as required by the Electrical Inspector shall be performed by the supplier at no extra cost to the Owner.

C. Control panels to be furnished on this project shall be wired to function according to schematics shown on the contract Drawings. In addition to the requirements shown on the Contract Drawings, the panels shall adhere to additional requirements as written herein, and in the utilization equipment specifications.

D. Enclosures shall be dead front with all operators’ devices accessible without opening the enclosure door. All relays, timers, terminal strips, etc., shall be mounted to a subpanel inside the enclosure. All wiring must be stranded and sized to be protected by a 20 A circuit breaker. Supplemental overcurrent protection may be used in lieu of oversized wiring. All panels mounted outside shall have operators devices mounted on an inner door with an outdoor door that is blank.

E. All terminal strips and lugs shall be of a type UL listed to terminate the size and quantity of wires encountered. Myers hubs shall be installed to maintain the enclosure rating where conduits enter NEMA 4X rated enclosures. The exterior of stainless steel NEMA 4X enclosures shall be unpainted. The exterior of NEMA 12 panels shall be painted ANSI 49 light gray, lacquer or enamel.

F. Enclosures shall be provided with a locking hasp and any exterior hardware shall be stainless steel or other corrosion resistant material. Enclosures for use in process or outdoor areas shall be NEMA 4X and enclosures for interior use in dry areas shall be NEMA 12, unless otherwise indicated.

G. Elementary control schematics and connection diagrams showing the spatial relationship of components and wiring shall be submitted for review. Also, a bill of materials, drawing of device arrangement on front, and enclosure fabrication drawings shall be submitted. Further, descriptive literature is required on all components. A copy of the shop drawings shall be

furnished and stored in a pocket inside the enclosure.

H. Sleeve type wire markers or other “permanent” type marker shall be installed on all wires, keynoted back to the elementary schematic or the connection diagram, and all terminals identified.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION (NOT USED

END OF SECTION