PART 1 GENERAL

1.1 SCOPE

.1 The contractor shall furnish short-circuit and protective device coordination studies as prepared by the electrical equipment manufacturer or an approved engineering firm.

.2 The contractor shall furnish an Arc Flash Hazard Analysis Study per the requirements set forth in NFPA 70E - Standard for Electrical Safety in the Workplace and CSA Z462-15 Workplace Electrical Safety. The arc flash hazard analysis shall be performed according to the IEEE 1584 equations that are presented in NFPA 70E, Annex D.

.3 The scope of the studies shall include all new distribution equipment supplied under this contract. Analysis of existing distribution equipment at the customer facility is not included unless it is necessary to complete analysis of new downstream equipment.

.4 The short circuit, arc flash and coordination study completed for the facility in 2012 is available to the contractor in PDF format if required. An electronic copy of the final building model must be turned over to the Departmental Representative in ETAP format after final acceptance of the studies.

1.2 REFERENCES

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

- .1 IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems.
- .2 IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.
- .3 IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis.
- .4 IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings.
- .5 IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.
- .6 IEEE 1584 – Guide for Performing Arc-Flash Hazard Calculations.

.2 American National Standards Institute (ANSI):

- .1 ANSI C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
- .2 ANSI C37.13 – Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures.
- .3 ANSI C37.010 – Standard Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
- .4 ANSI C 37.41 – Standard Design Tests for High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories.

.3 The National Fire Protection Association (NFPA)

.1 NFPA 70 - National Electrical Code, latest edition.

.2 NFPA 70E – Standard for Electrical Safety in the Workplace.

.4 Canadian Standards Association (CSA)

.1 CSA Z462-15 Workplace Electrical Safety.

1.3 SUBMITTALS FOR REVIEW/APPROVAL

.1 The short-circuit and protective device coordination studies shall be submitted to the design engineer prior to receiving final approval of the distribution equipment shop drawings and/or prior to release of equipment drawings for manufacturing. If formal completion of the studies may cause delay in equipment manufacturing and/or project schedule, approval from the engineer may be obtained for preliminary submittal of sufficient study data to ensure that the selection of device and characteristics will be satisfactory.

1.4 SUBMITTALS FOR CONSTRUCTION

.1 The results of the short-circuit, protective device coordination and arc flash hazard analysis studies shall be summarized in a final report in PDF format.

.2 The report shall include the following sections:

.1 One-line diagram showing protective device ampere ratings and associated designations, cable size and lengths, transformer kVA and voltage ratings, motor and generator kVA ratings, and switchgear/switchboard/panelboard designations.

.2 Descriptions, purpose, basis and scope of the study.

.3 Tabulations of the worst-case calculated short circuit duties as a percentage of the applied device rating (automatic transfer switches, circuit breakers, fuses, etc.); the short circuit duties shall be upward-adjusted for X/R ratios that are above the device design ratings.

.4 Protective device time versus current coordination curves with associated one line diagram identifying the plotted devices, tabulations of ANSI protective relay functions and adjustable circuit breaker trip unit settings.

.5 Fault study input data, case descriptions, and current calculations including a definition of terms and guide for interpretation of the computer printout.

.6 Incident energy and flash protection boundary calculations.

.7 Comments and recommendations for system improvements, where needed.

.8 Executive Summary including source of information and assumptions made.

1.5 QUALIFICATIONS

.1 The short-circuit, protective device coordination and arc flash hazard analysis studies shall be conducted under the supervision and approval of a Registered Professional Electrical Engineer skilled in performing and interpreting the power system studies.

.2 The Registered Professional Electrical Engineer shall be a full-time employee of the equipment manufacturer or an approved engineering firm.

.3 The Registered Professional Electrical Engineer shall have a minimum of five (5) years of experience in performing power system studies.

.4 The equipment manufacturer or approved engineering firm shall demonstrate experience with Arc Flash Hazard Analysis by submitting names of at least ten actual arc flash hazard analyses it has performed.

PART 2 PRODUCTS

2.1 STUDIES

.1 Contractor to furnish short-circuit and protective device coordination studies as prepared by equipment manufacturer or an approved engineering firm. The coordination study shall begin with the utility company's feeder protective device and include all of the electrical protective devices. 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.

.2 The contractor shall furnish an Arc Flash Hazard Analysis Study per NFPA 70E - Standard for Electrical Safety in the Workplace and CSA Z462-15 Workplace Electrical Safety.

2.2 DATA COLLECTION

.1 Contractor shall furnish all data as required by 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 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.

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

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

.4 If applicable, include fault contribution of existing motors in the study. The Contractor shall obtain required existing equipment data, if necessary, to satisfy the study requirements.

.5 A copy of the most recent (2012) arc flash/coordination/short circuit study that was completed for the facility can be provided to assist with the data gathering efforts. Some of the recommendations of this report have been implemented. The contractor must confirm on site the exact extent of corrective work completed.

2.3 SHORT-CIRCUIT AND PROTECTIVE DEVICE EVALUATION STUDY

.1 Use actual conductor impedances if known. If unknown, use typical conductor impedances based on IEEE Standard 141, latest edition.

.2 Transformer design impedances and standard X/R ratios shall be used when test impedances are not available.

.3 Provide the following:

- .1 Calculation methods and assumptions.
- .2 Selected base per unit quantities.
- .3 One-line diagram of the system being evaluated with available fault at each bus, and interrupting rating of devices noted.
- .4 Source impedance data, including electric utility system and motor fault. contribution characteristics.
- .5 Tabulations of calculated quantities.
- .6 Results, conclusions, and recommendations.

.4 Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault at each:

- .1 Electric utility's supply termination point.
- .2 Incoming switchgear.
- .3 Unit substation primary and secondary terminals.
- .4 Low voltage switchgear.
- .5 Standby generators and automatic transfer switches.
- .6 Branch circuit panelboards.
- .7 Other significant locations throughout the system.

.5 For grounded systems, provide a bolted line-to-ground fault current study for areas as defined for the three-phase bolted fault short-circuit study.

.6 Protective Device Evaluation:

- .1 Evaluate equipment and protective devices and compare to short circuit ratings.
- .2 Adequacy of switchgear, motor control centers, and panelboard bus 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.
- .5 Notify owner in writing, of existing, circuit protective devices improperly rated for the calculated available fault current.

2.4 PROTECTIVE DEVICE COORDINATION STUDY

.1 Proposed protective device coordination time-current curves (TCC) shall be displayed on log-log scale graphs.

.2 Include on each curve sheet, a complete title and one-line diagram with legend identifying the specific portion of the system covered.

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

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

.5 Plot the following characteristics on the curve sheets, where applicable:

- .1 Electric utility's overcurrent protective device.
- .2 Medium voltage equipment overcurrent relays.
- .3 Medium and low voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
- .4 Low voltage equipment circuit breaker trip devices, including manufacturer's tolerance bands.
- .5 Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
- .6 Conductor damage curves.
- .7 Ground fault protective devices, as applicable.
- .8 Pertinent motor starting characteristics and motor damage points, where applicable.
- .9 Pertinent generator short-circuit decrement curve and generator damage point.

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

2.5 ARC FLASH HAZARD ANALYSIS

.1 The arc flash hazard analysis shall be performed according to the IEEE 1584 equations that are presented in NFPA70E, Annex D.

.2 The flash protection boundary and the incident energy shall be calculated at all significant locations in the electrical distribution system (switchboards, switchgear, panelboards, busway and splitters) where work could be performed on energized parts.

.3 The Arc-Flash Hazard Analysis shall include all MV, 600V locations and significant locations in 240 volt and 208 volt systems fed from transformers equal to or greater than 125 kVA where work could be performed on energized parts.

.4 Safe working distances shall be based upon the calculated arc flash.

.5 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. Ground overcurrent relays should not be taken into consideration when determining the clearing time when performing incident energy calculations.

.6 The short-circuit calculations and the corresponding incident energy calculations for multiple system scenarios must be compared and the greatest incident energy must be uniquely reported for each equipment location. Calculations must be performed to represent the maximum and minimum contributions of fault current magnitude for all normal and emergency operating conditions. The minimum calculation will assume that the utility contribution is at a minimum and will assume a minimum motor contribution (all motors off). Conversely, the maximum calculation will assume a maximum contribution from the utility and will assume the maximum amount of motors to be operating. Calculations shall take into consideration the parallel operation of synchronous generators with the electric utility, where applicable.

.7 The incident energy calculations must consider the accumulation of energy over time when performing arc flash calculations on buses with multiple sources. Iterative calculations must take into account the changing current contributions, as the sources are interrupted or decremented with time. Fault contribution from motors and generators should be decremented as follows:

.1 Fault contribution from induction motors should not be considered beyond 3-5 cycles.

.2 Fault contribution from synchronous motors and generators should be decayed to match the actual decrement of each as closely as possible (e.g. contributions from permanent magnet generators will typically decay from 10 per unit to 3 per unit after 10 cycles).

.8 For each equipment location with a separately enclosed main device (where there is adequate separation between the line side terminals of the main protective device and the work location), calculations for incident energy and flash protection boundary shall include both the line and load side of the main breaker.

.9 Where performing incident energy calculations on the line side of a main breaker (as required per above), the line side and load side contributions must be included in the fault calculation.

.10 Mis-coordination should be checked amongst all devices within the branch containing the immediate protective device upstream of the calculation location and the calculation should utilize the fastest device to compute the incident energy for the corresponding location.

.11 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 section B.1.2. Where it is not physically possible to move outside of the flash protection boundary in less than 2 seconds during an arc flash event, a maximum clearing time based on the specific location shall be utilized.

2.6 REPORT SECTIONS

.1 Input data shall include but not be limited to the following:

.1 Utility 3-phase and L-G available contribution with associated X/R ratios.

.2 Feeder input data including feeder type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic) and conductor material (copper or aluminum).

.3 Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, % taps and phase shift.

.4 Reactor data, including voltage rating, and impedance.

.5 Generation contribution data, (synchronous generators and Utility), including short-circuit reactance (X"d), rated MVA, rated voltage, three-phase and single line-ground contribution (for Utility sources) and X/R ratio.

.6 Motor contribution data (induction motors and synchronous motors), including shortcircuit reactance, rated horsepower or kVA, rated voltage, and X/R ratio.

.2 Short-Circuit Output Data shall include, but not be limited to the following reports:

.1 Low voltage Fault Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each application location:

.1 Voltage

.2 Calculated fault current magnitude and angle

.3 Fault point X/R ratio

.4 Equivalent impedance

.2 Momentary Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:

.1 Voltage

.2 Calculated symmetrical fault current magnitude and angle

.3 Fault point X/R ratio

.4 Calculated asymmetrical fault currents

.1 Based on fault point X/R ratio

.2 Based on calculated symmetrical value multiplied by 1.6

.3 Based on calculated symmetrical value multiplied by 2.7

.5 Equivalent impedance.

.3 Interrupting Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:

.1 Voltage.

.2 Calculated symmetrical fault current magnitude and angle.

.3 Fault point X/R ratio.

.4 No AC Decrement (NACD) Ratio.

.5 Equivalent impedance.

.6 Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a symmetrical basis.

.7 Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a total basis.

.3 Recommended Protective Device Settings:

.1 Phase and Ground Relays:

.1 Current transformer ratio.

.2 Current setting.

.3 Time setting.

.4 Instantaneous setting.

.5 Recommendations on improved relaying systems, if applicable.

.2 Circuit Breakers:

.1 Adjustable pickups and time delays (long time, short time, ground)

.2 Adjustable time-current characteristic.

.3 Adjustable instantaneous pickup.

.4 Recommendations on improved trip systems, if applicable.

.4 Incident energy and flash protection boundary calculations:

.1 Arcing fault magnitude.

.2 Protective 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.

PART 3 <u>EXECUTION</u>

3.1 FIELD ADJUSTMENT

.1 Adjust relay and protective device settings according to the recommended settings table provided by the coordination study.

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

.3 Notify Departmental Representative in writing of any required major equipment modifications.

3.2 ARC FLASH WARNING LABELS

.1 The contractor of the Arc Flash Hazard Analysis shall provide a 3.5 in. x 5 in. thermal transfer type label of high adhesion polyester for each work location analyzed.

.2 All labels will be based on recommended overcurrent device settings and will be provided after the results of the analysis have been presented to the owner and after any system changes, upgrades or modifications have been incorporated in the system.

.3 The label shall have an orange header with the working: "WARNING: ARC FLASH HAZARD" and shall include the following information, at a minimum:

.1 Location designation

.2 Nominal voltage

.3 Flash protection boundary

.4 Hazard risk category

.5 Incident energy

.6 Working distance

.7 Engineering report number, revision number and issue date.

.4 Labels shall be machine printed, with no field markings.

.5 Arc flash labels shall be provided in the following manner and all labels shall be based on recommended overcurrent device settings.

.1 For each 600, 480 and applicable 208 volt panelboard, one arc flash label shall be provided.

.2 For each motor control center, one arc flash label shall be provided.

.3 For each low voltage switchboard, one arc flash label shall be provided.

.4 For each switchgear, one flash label shall be provided.

.5 For medium voltage switches one arc flash label shall be provided.

3.3 ARC FLASH TRAINING

.1 The contractor of the Arc Flash Hazard Analysis shall train the Owner's qualified electrical personnel of the potential arc flash hazards associated with working on energized equipment (minimum of 4 hours).

END OF SECTION