SECTION 26 05 73.19

SHORT-CIRCUIT/COORDINATION STUDY/ARC FLASH HAZARD ANALYSIS

PART 1 GENERAL

1.01 SCOPE

A. Contractor shall furnish and submit for approval to the Engineer of Record signed and sealed short-circuit and protective device coordination studies, and Arc Flash Risk Assessment study in accordance with the requirements of this Section.

B. The scope of the studies shall include all new distribution equipment supplied by the equipment Manufacturer under this contract.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. The work shall proceed in accordance with the following specifications sections, bound herein:

1. Section 01 35 13 (01100) – “Special Project Procedures”
2. Section 01 35 26 (01016) – “Safety Requirements and Protection of Property”
3. Section 01 35 53 (01140) – “Security”
4. Section 01 42 13 – “Abbreviations and Anacronyms”
5. Section 01 78 23 (01730) – “Operation and Maintenance Data”
6. Section 26 00 00 (16010) – “Basic Electrical Requirements”

1.03 REFERENCES

A. Below list is not all inclusive and it is the responsibility of the Contractor to comply with all applicable requirements whether included in this list or not.

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 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

c. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis

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

e. IEEE 551 – Recommended Practice for Calculating Short Circuit Currents in Industrial and Commercial Power Systems

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

g. IEEE 1584 - Guide for Performing Arc Flash Hazard Calculations

2. American National Standards Institute (ANSI):

a. ANSI 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 Z535.4 – Standard for Product Safety Signs and Labels.

3. The National Fire Protection Association (NFPA)

a. NFPA 70 - National Electrical Code, latest edition

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

1.04 SUBMITTALS

A. The Contractor shall furnish an Arc Flash Risk Assessment Study per the requirements set forth in NFPA 70E - Standard for Electrical Safety in the Workplace. The arc flash risk assessment shall be performed according to the IEEE 1584 equations that are presented in NFPA70E, Article 130.5, Annex D.

B. The short-circuit and protective device coordination studies shall be as prepared by the electrical equipment manufacturer or an approved engineering firm. It shall include site specific arc flash warning labels.

C. Study reports shall be signed and sealed by the Registered/Licensed Professional Electrical Engineer approving the studies.

D. For Review/Approval

1. The short-circuit and protective device coordination studies shall be submitted to the Engineer of Record prior to receiving final approval of the distribution equipment shop drawings and/or prior to release of equipment drawings for manufacturing.

2. If formal completion of the studies may cause delay in equipment manufacturing, 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.

E. For Construction

1. The results of the short-circuit, protective device coordination and arc flash risk assessment studies shall be summarized in a final report. A complete final report shall be provided in PDF format on CD/DVD, USB drive and uploaded using the applicable Department's system.

2. Following best practices, the Contractor is to provide the study project files to the Owner in electronic format to allow the Owner to review all aspects of the project input data and reprint arc flash labels, one-line diagrams, reports etc. The electronic project files are critical for disaster recovery and maintaining the power system. In addition, a copy the Power*Tools for Windows (PTW) Viewer program is required to accompany the electronic project files.

3. The report shall include the following sections:

   a. Executive Summary.

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

   c. Tabulations of circuit breaker, fuse, and other protective device ratings versus calculated short circuit duties

   d. Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip unit settings, fuse selection

   e. Specify PPE required for protection

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

   g. Details of the incident energy and flash protection boundary calculations

   h. Recommendations for system improvements, where needed

   i. One-line diagram

4. Arc flash labels for all applicable components, as herein specified, shall also be provided in hard copy.

1.05 MINIMUM REQUIREMENTS AND EXPERIENCE

A. License Requirements

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

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

B. Experience

1. The Registered/Licensed Professional Electrical Engineer shall have a

minimum of 5 years of experience in performing power system studies.

2. The equipment manufacturer or approved engineering firm shall demonstrate experience with Arc Flash Risk Assessment by submitting names of at least 10 actual arc flash risk assessment it has performed in the past year.

3. The reference for each Arc Flash Risk Assessment reference provided shall include:

   a. Name of the Engineering firm and the Registered/Licensed Professional Electrical Engineer for each reference.

   b. The client's name and address including a contact person and phone number for each reference.

PART 2 PRODUCTS

2.01 COMPUTER ANALYSIS SOFTWARE

A. The studies shall be performed using the latest revision of the SKM Systems Analysis Power*Tools for Windows (PTW) software program.

2.02 ARC FLASH WARNING LABELS

A. The Contractor of the Arc Flash Risk Assessment shall provide for each work location analyzed a 4 in. x 6 in. thermal transfer type label of high adhesion polyester in compliance with the following:

1. Label background shall be white color

2. Label lettering shall be black color

3. "DANGER" word shall be white color with red background.

PART 3 EXECUTION

3.01 DATA COLLECTION

A. Contractor shall furnish all data as required by the power system studies. The Engineer performing the short-circuit, protective device coordination and arc flash risk assessment 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.

B. Source combination may include present and future motors and generators.

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

D. 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.

3.02 SHORT-CIRCUIT AND PROTECTIVE DEVICE EVALUATION STUDY

A. Use actual conductor impedances if known. If unknown, use typical conductor impedances based on IEEE Standard 141-1993.

B. Transformer design impedances shall be used when test impedances are not available.

C. Provide the following:

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

D. 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. Motor control centers
6. Standby generators and automatic transfer switches
7. Branch circuit panelboards
8. Other significant locations throughout the system

E. 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.

F. 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 bars to withstand short-circuit stresses.
3. Notify the Department in writing, of existing, circuit protective devices improperly rated for the calculated available fault current.

3.03 PROTECTIVE DEVICE COORDINATION STUDY

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

B. Include on each TCC graph, a complete title and one-line diagram with legend identifying the specific portion of the system covered.

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

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

E. Plot the following characteristics on the TCC graphs, 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 generators short-circuit decrement curve and generator damage point
10. The largest feeder circuit breaker in each motor control center and applicable panelboard

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

3.04 ARC FLASH RISK ASSESSMENT

A. The arc flash risk assessment shall be performed according to the IEEE 1584 equations that are presented in NFPA70E, Annex D.

B. 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, transfer switches, panelboards, busway, splitters, meter sockets, disconnect switches, control panels, transformers, etc) where work could be performed on energized parts.

C. The Arc Flash Risk Assessment shall include all 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.

D. Safe working distances shall be based upon the calculated arc flash boundary considering an incident energy of 1.2 cal/cm^2.

E. 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

F. 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 number of motors to be operating. Calculations shall take into consideration the parallel operation of synchronous generators with the electric utility, where applicable.

G. 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 consider 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).

H. 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.

I. When 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.

J. Miscoordination 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.

K. 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.

3.05 REPORT SECTIONS

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

1. 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).
2. Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, % taps and phase shift.
3. Reactor data, including voltage rating, and impedance.
4. 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.
5. Motor contribution data (induction motors and synchronous motors), including short-circuit reactance, rated horsepower or kVA, rated voltage, and X/R ratio.

B. 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 applicable location:
    a. Voltage
    b. Calculated fault current magnitude and angle
    c. Fault point X/R ratio
    d. 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:
    a. Voltage
    b. Calculated symmetrical fault current magnitude and angle
    c. Fault point X/R ratio
    d. 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

e. 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:

a. Voltage

b. Calculated symmetrical fault current magnitude and angle

c. Fault point X/R ratio

d. No AC Decrement (NACD) Ratio

e. Equivalent impedance

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

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

C. Recommended Protective Device Settings:

1. Phase and Ground Relays:

a. Current transformer ratio

b. Current setting

c. Time setting

d. Instantaneous setting

e. Recommendations on improved relaying systems, if applicable

2. Circuit Breakers:

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

b. Adjustable time-current characteristic

c. Adjustable instantaneous pickup

d. Recommendations on improved trip systems, if applicable.

D. 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

9. PPE required

*Applicable only when using the arc flash Personal Protective Equipment (PPE) category method.

3.06 FIELD ADJUSTMENT

A. Adjust relay and protective device settings according to the recommended settings table provided by the coordination study. Field adjustments to be completed by the engineering service division of the equipment manufacturer under the Startup and Acceptance Testing contract portion.

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

C. Notify the Department in writing of any required major equipment modifications.

3.07 ARC FLASH WARNING LABELS

A. The contractor of the Arc Flash Risk Assessment shall provide a 4 in. x 6 in. thermal transfer type label of high adhesion polyester for each work location analyzed.

B. 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.

C. The label 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. Company name performing the study
8. Company File number
9. Date study performed
10. PPE rating
11. Engineering report number, revision number and issue date

*Applicable only when using the arc flash PPE category method.

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

E. 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 arc flash label shall be provided
5. For medium voltage switches one arc flash label shall be provided
6. For each industrial control panel, one arc flash label shall be provided

F. Labels shall be field installed by the engineering service division of the equipment manufacturer under the Startup and Acceptance Testing contract portion.

END OF SECTION