SECTION 26 05 73.19.12

SHORT-CIRCUIT/COORDINATION STUDY/ARC FLASH RISK ASSESSMENT NEW BUILDINGS

PART 1 GENERAL

1.01 SCOPE

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

B. 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 NFPA 70E, Annex D.

C. The scope of the studies shall include all new electrical distribution equipment supplied by the equipment manufacturer under this contract as well as all directly affected existing electrical distribution equipment at the customer facility.

1.02 RELATED SECTIONS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.03 REFERENCES

A. 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

B. 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.

C. The National Fire Protection Association (NFPA)
   1. NFPA 70 - National Electrical Code, latest edition
   2. NFPA 70E – Standard for Electrical Safety in the Workplace, latest edition

D. American Society for Testing and Materials
   1. ASTM F1506 – Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs

1.04 SUBMITTALS FOR REVIEW/APPROVAL

A. 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, 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.

1.05 SUBMITTALS FOR CONSTRUCTION

A. The results of the short-circuit, protective device coordination and arc flash risk assessment studies, including all drawings, shall be summarized in a final report. The report shall be posted to Box for downloading by Clemson University authorized personnel and shall include pdfs of all documents in the report and shall include the AutoCAD format drawings required by the study, and shall include the SKM PTW Backup of the project file.

B. The contractor is required to provide the study SKM PTW Backup project files to the Owner in electronic format for viewing and for adding to the Owner's SKM Software master project file. This will allow the Owner to review all aspects of the project. The electronic format files shall be compatible with SKM licensed software, latest version.

C. The report shall include the following sections:
   1. Executive Summary.
   2. Descriptions, purpose, basis and scope of the study
   3. Tabulations of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties
   4. Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip unit settings, fuse selection
   5. Fault current calculations including a definition of terms and guide for interpretation of the computer printout
   6. Details of the incident energy and flash protection boundary calculations
   7. Recommendations for system improvements, where needed
   8. SKM one-line diagrams showing the SKM system one-line diagrams with the SKM datablock showing the following. The SKM one-lines shall be totally created within the SKM project software. All SKM one-lines shall be viewable with the SKM PTW software project.
      a. Cable size and quantity and length
      b. Bus name and incident energy at working distance

c. Device name and symbol including, but not limited to, disconnect switches, circuit breakers, MCPs, fuses, VFDs, transformers, UPSs, starters, motors, cables, capacitors, reactors, generators, non-motor loads, transfer switches, and other symbols as required
d. Device name and frame/model number
e. Device name and frame/model and sensor trip for fuses
f. Device name and frame/model and sensor/trip and plug and settings for circuit breakers
g. Other data pertinent to the study.

9. AutoCAD one-line diagram(s) modeling the complete electrical system. This includes all three phase circuits and all single phase circuits larger than 20 amperes.
10. AutoCAD building floor plan(s) showing the location and component name of all electrical devices to receive an arc flash label.
11. Drawing sizes: Single line diagrams created in SKM, AutoCAD location floor plans and AutoCAD single line diagrams shall be sized to ANSI D drawing size such that when printed on an ANSI B drawing size (11x17 inches Tabloid) print that the content and text are readable without the use of a magnifying instrument. North Arrows representing true North and graphic scale shall be placed on all plan drawings.
12. Photographs: Provide photograph files of all equipment that is included in the Arc Flash Study. Photograph file names shall reflect equipment in the photograph. Photograph names shall begin with the building four digit number. Photograph file format shall be jpg format or other common file format as approved by the Owner. Photograph density shall be 10 megapixel or better. All images, including text and symbols, etc, shall remain in focus when using the zoom-in feature of the viewing software of at least 400 percent zoom. Photographs subject matter shall include location, nameplates or markings, manufacturer model number and catalog number, ampere and voltage ratings, manufacturer nameplate catalog number, series number, protective devices and data, etc.

D. Arc flash labels shall be provided in hard copy using the PTW arc flash label format provided by Clemson University to the Study Provider. Stick-on arc flash labels shall not be provided until the complete study has final approval of the Owner. Copies of labels shall be provided in PDF format for approval purposes.

1.06 QUALIFICATIONS

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

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

C. The Registered Professional Electrical Engineer shall have a minimum of five (5) years of experience in performing power system studies of similar scope and size of studies required herein.

D. The equipment manufacturer or approved engineering firm shall demonstrate experience with Arc Flash Risk Assessment by submitting names of at least three (3) actual arc flash

risk assessment studies using the Incident Energy Analysis Method it has performed in the past year.

1.07 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.

B. SKM has an extensive library including, but not limited to, library files for circuit breaker trip units, fuses, conductors, etc. However, in the event that SKM does not have in their standard library the files and data for the actual devices and equipment encountered in the facility under study, it is the Contractor's responsibility to obtain the necessary and required files and data from SKM, and to obtain any and all other data and information to complete the arc flash and other studies specified herein.

1.08 BUILDING NUMBER

A. The Owner will designate to the contractor a unique four-digit number, that may begin with zero(s), to be used in the Component Name for all buses, components and devices and shall be used in the names of all one-line drawings, TCC drawings, TCC one-lines and any other document produced by or within the SKM software. This number shall precede the additional characters of the component name so that a unique descriptive field is assigned to each bus, component or device in the project. Duplicate names are not allowed, either in this study or in subsequent studies or scenarios. The length of all component names shall be selected as 30-characters in the PTW software.

PART 2 PRODUCT

2.01 STUDIES

A. Contractor to furnish short-circuit and protective device coordination and equipment evaluation studies as prepared by equipment manufacturer or an approved engineering firm.

B. The contractor shall furnish an Arc Flash Risk Assessment Study per NFPA 70E - Standard for Electrical Safety in the Workplace, reference Article 130.5, Article 130.5(G) and Annex D. Arc Flash Risk Assessment shall use the Incident Energy Analysis Method per NFPA 70E - 2021, Article 130.5(G).

C. All three phase circuits are to be included in the study. All phase-to-phase two pole circuits 20 amps and larger feeding equipment, such as non-fused and fused disconnect switches, and/or likely to require inspection shall be included in the study. Individual single phase and phase-to-phase two pole circuits rated less than 20 amps feeding general purpose receptacles shall not be included in the studies.

D. Calculations for all voltages and transformer kVA sizes shall be from equations.

2.02 DATA COLLECTION

A. Contractor shall collect and 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 shall include present and future motors and generators.

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

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

E. Data Collection shall be the responsibility of the Contractor and shall include, as a minimum, the following:
   1. Manufacturer of all protective devices required for the studies, including but not limited to:
      a. Circuit breakers, catalog number, model numbers, series number, etc
      b. Circuit breaker trip types and ranges, sensor sizes, catalog number and ranges in amperes
      c. Disconnect switches
      d. Fused Disconnect switches
      e. Fuse types and ampere ratings
      f. Electronic/solid state trip units including all functions and ranges
      g. All existing settings of protective devices
      h. Date of manufacture
      i. Ampere interrupting rating, including load break rating, AIC and momentary ratings in kA and voltage ratings
      j. Conductor sizes, types, lengths, types of raceway, etc
      k. Relay setting, current transformer ratios
      l. Generator short-circuit characteristics
   2. Verify nomenclature to be used for all components and all devices in the study with the Owner.
   3. Field inspections shall be coordinated with the Owner and shall be performed complying with the Owners safety requirements and applicable electrical work safety standards.

2.03 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 and/or pad mounted service transformers primary and secondary terminals
4. Low voltage switchgear or switchboard
5. Step-down and/or step-up transformers
6. Motor control centers
7. Standby and/or emergency generators
8. Branch circuit panelboards and/or distributions boards
9. Disconnect switches, fused and non-fused
10. Adjustable speed drives
11. Automatic and manual transfer switches both normal and emergency supply
12. Automatic and manual transfer switches load side considering separately the normal and emergency power sources mode
13. All three (3)-phase circuits and other circuits as specified herein.
14. Other significant loads 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 available voltage and short circuit ratings
2. Adequacy of switchgear, motor control centers, and panelboards and other system equipment to withstand available voltage and short-circuit stresses
3. Notify Owner in writing of circuit protective devices improperly specified or rated for the available voltage and phase and calculated available fault current.

2.04 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 with the one-line diagram on the left and the TCC on the right side using 11 inch x 17 inch landscape format as approved by the Owner.

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 generator short-circuit decrement curve and generator damage point

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

2.05 ARC FLASH RISK ASSESSMENT

A. The Arc Flash Risk Assessment shall be performed according to the IEEE 1584 equations that are presented in NFPA 70E, 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, panelboards, busway and splitters) where work could be performed on energized parts.

C. The Arc Flash Risk Assessment shall include all locations for all voltages including 240 volt and 208 volt systems regardless of transformer kVA size to which the circuits are connected. The exception for these systems fed from transformers equal to or less than 125kVA shall not be allowed.

D. Safe working distances shall be based upon the calculated arc flash boundary considering an incident energy of 1.2 cal/cm^2. The selection of arc-rated clothing and other PPE shall be based on NFPA 70E-2021, Table 130.5(G). For incident energy exposures less than 1.2 cal/cm^2 , PPE shall meet the requirements of NFPA 70E-2021 and ASTM F1506 as a minimum.

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 amount 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 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).

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. 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. However, the arc flash label provided shall be provided with results based on the protective device closest to and immediately ahead of the faulted bus.

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 1584-2002 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.

2.06 REPORT SECTIONS

A. Input data shall include, but not be limited to, the following:
   1. Feeder input data including feeder type (cable or bus), insulation material, size, actual circuit 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 sub-transient 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. PPE
8. Recommendations for arc flash energy reduction

PART 3 EXECUTION

3.01 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 Owner in writing of any required major equipment modifications.

D. Any and all equipment shutdowns and/or de-energizations shall be submitted in writing to and approved by the Owner in writing prior to these equipment shutdowns and/or de-energizations.

3.02 ARC FLASH WARNING LABELS

A. The contractor of the Arc Flash Risk Assessment shall provide a 3.33 in. x 4 in. laser printed type label of high adhesion polyester for each work location analyzed. Labels shall be manufactured by Avery, Number 5524, no substitutions.

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 approved system changes, upgrades or modifications have been incorporated in the system.

C. The label shall include the following information, at a minimum as contained in the SKM label form to be given by Clemson University to the study contractor:
1. Flash Protection Boundary
2. Incident Energy
3. Working Distance

4. PPE
5. Nominal system voltage
6. Shock Risk When Cover Is Removed
7. Glove Class
8. Limited Approach
9. Restrictive Approach
10. Location Designation
11. Protective Device
12. Maximum Short Circuit Amperes
13. Issue Date.

D. Labels shall be laser ink jet machine printed, with no field markings. On the Arc Flash labels, the “LOCATION” field and the “PROTECTIVE DEVICE” field are intended to be descriptive of the item for which the incident energy is being calculated and displayed and for the protective device that provides overcurrent protection for the item described in the “LOCATION” field. The “LOCATION” description is to include the building number as the first four digits of the component name followed by the name and number of the item. The “PROTECTIVE DEVICE” description is to include the building number as the first four digits of the component name followed by the name of the item or device that contains the protective device followed by the position numbers in the device containing the overcurrent device. Some examples are as follows:
   1. “LOCATION”: XXXX PANEL LP1 “PROTECTIVE DEVICE”: XXXX PNL 1DPB – 37/39/41
   2. “LOCATION”: XXXX AHU1 DSw “PROTECTIVE DEVICE”: XXXX MCC2 – 3F
   3. “LOCATION”: XXXX CTwr P – 1 VFD “PROTECTIVE DEVICE”: XXXX MDP – 12/14/16
   4. In general, component names should be names of the actual equipment encountered in the arc flash study.

E. Arc flash labels shall be provided in the following manner and all labels shall be based on approved overcurrent device settings:
   1. Panelboards and/or distribution panels, one or more arc flash labels shall be provided
   2. For each motor control center, one or more arc flash labels shall be provided
   3. For each low voltage switchboard, one or more arc flash labels shall be provided
   4. For each switchgear, one or more arc flash labels shall be provided. Additional labels are required for rear accessible gear.
   5. For medium voltage switches, one arc flash label shall be provided
   6. For each step-down and/or step-up transformer, two arc flash labels shall be provided, one for the primary side and one for the secondary side
   7. Fused or non-fused individual disconnect switches, one arc flash label shall be provided
   8. Individual motor controller, one arc flash label shall be provided

9. Automatic and/or manual transfer switches, provide one label for the normal supply side, one label for the emergency supply side, and multiple labels may be required for the transfer switch load side circuits based on incident energy calculated
10. Individual circuit breakers, one arc flash label shall be provided
11. Variable(adjustable) speed controllers, one arc flash label shall be provided. Additional labels may be required depending on the variable(adjustable) speed controller operating mode.

F. In the event that equipment evaluated in the study fails the equipment evaluation report, a label shall be provided similar to the Arc Flash label except with a red background with the word DANGER, in black letters, printed at the top of the label. However, arc flash information shall not be included on the label. The label shall also include appropriate wording to indicate that the equipment is to be de-energized prior to being worked on. The fields for LOCATION, PROTECTIVE DEVICE and MAXIMUM SHORT CIRCUIT AMPERES shall also be included on the label.

G. Labels shall be field installed by the Arc Flash study contractor.

3.03 ARC FLASH TRAINING

A. As an option, the contractor of the Arc Flash Risk Assessment shall train the owner’s qualified electrical personnel of the potential arc flash risks associated with working on energized equipment (minimum of 4 hours). The training shall be certified for continuing education units (CEUs) by the International Association for Continuing Education Training (IACET) or equivalent.