

## **SECTION 26 05 73**

### **SHORT CIRCUIT ANALYSIS/COORDINATION STUDY/FAULT STUDY**

#### **PART 1 - GENERAL**

##### 1.1 RELATED DOCUMENTS:

- A. The Conditions of the Contract and applicable requirements of Divisions 0 and 1 and Section 26 00 01, "Electrical General Provisions", govern this Section.

##### 1.2 DESCRIPTION OF THE WORK:

- A. General:

#### **[EDIT PARAGRAPH BELOW AND LEAVE PARAGRAPH BOLD IN FINAL SECTION]**

1. **The Short Circuit Analysis, Protective Device Coordination Study[, Emergency Power System Selective Coordination Study] and Arc Flash and Electrical Hazard Studies specified in this section shall be completed and submitted prior to submitting submittals for [switchgear,] switchboards, [motor control centers,] distribution panels, panelboards, enclosed circuit breakers and other electrical gear with short circuit or interrupting ratings.**
2. The Electrical Contractor shall provide the Engineer with a Power System Short Circuit Analysis, Protective Device Coordination Study[, **Emergency Power System Selective Coordination Study**] and Arc Flash and Electrical Hazard Study. These analysis's and studies shall include all power distribution systems, beginning at the electric service point from the Electric Utility Company [**and emergency power source(s)**] to the secondary buses of each panelboard as described hereafter.
3. shall be prepared by and certified with a registration seal and signature of a Registered Professional Engineer. The Engineer shall be qualified by experience in preparation of studies having similar requirements and of similar magnitude to that specified in this section of the Specifications.
4. The Short Circuit Analysis shall terminate at each branch bus at the lowest utilization voltage secondary bus where the symmetrical short circuit RMS amperes, total source plus all motor contribution, is less than 10,000 amperes for 208/240 volts and 14,000 amperes for 480 volts. It is the intent of these Specifications to determine all locations in the entire electrical system where the symmetrical short circuit amperes meets or exceeds 10,000 amperes at 208 volts and 14,000 amperes at 480 volts. The short circuit analysis shall compare interrupting rating of all installed electrical protective devices connected to each bus included in the study with that of the available fault current at the load terminals of each protective device. Appropriate recommendations shall be made for corrective action in the conclusions of the report where the interrupting rating of electrical equipment is exceeded by the available fault current.
5. The Protective Device Coordination Study shall start at the electric service and include all electrical distribution equipment protective devices with adjustable trip units, relay settings or options for fuse types. The curves and settings for the Power Company protective devices shall be included in the scope of this study. The coordination plots shall terminate with the first non-adjustable overcurrent device or devices downstream of all protective devices with an adjustable trip unit, relay settings or options for fuse types.

The protective device study shall include a separate analysis for phase and ground protection.

6. **[The Emergency Power System Selective Coordination Study shall comply with all applicable NEC requirements and shall start at the electric service and emergency power source(s) and include all electrical distribution equipment protective devices to and including the final branch circuit protective devices serving applicable emergency loads. The curves and settings for the Power Company protective devices shall be included in the scope of this study. The coordination plots shall terminate with the final branch circuit protective devices serving applicable emergency loads. The protective device study shall include a separate analysis for phase and ground protection.]**
7. The Arc Flash and Electrical Hazard Study comply with applicable NEC and OSHA requirements and shall include calculating the Arc Flash and establishing the Electrical Hazard rating for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
8. The Contractor shall obtain all lengths of cable from the electrical drawings and, where not shown the entire length of the run, from Contractor estimated lengths to longest possible lengths. All other equipment ratings shall be obtained by the Contractor from the equipment manufacturer's and/or suppliers.

B. Short Circuit Analysis: The Analysis shall include the following:

1. A schematic one-line drawing of the entire electrical system included in the study, from the power company system including the point of delivery, to each primary transformer, and including all main secondary buses of each transformer included in the study. Secondary buses shall include multiple secondary transformations within the scope of the study. Each device shall be identified using project assigned identification labels. Each motor 10 hp and larger shall be shown and identified. Each bus shall be assigned an identification number.
2. Source voltage and impedance data shall be given in the analysis, including reactance and resistance in OHMS to the source, and available symmetrical and asymmetrical short circuit amperes at the point of delivery of electrical power. Short circuit amperes shall be based on an assumed bolted 3 phase short circuit.
3. At each bus, including buses of all primary protective and switching devices, primary and secondary of all transformers, all secondary main and feeder breakers, and all secondary devices and panelboards within the scope of the study, the following shall be calculated for assumed bolted 3 phase short circuits.
  - a. Symmetrical RMS short circuit amperes, calculated using total source and motor contribution reactance and resistance values.
  - b. Asymmetrical average 3 phase RMS amperes at 1/2 cycle, calculated using actual total source and motor contribution X/R ratio.
  - c. Reactance ("X") and Resistance ("R") in OHMS at the voltage of the device being examined, including both The Power Company source and all motor contributions.
4. Calculation sheets for cable sections shall indicate voltage, wire size, cable length, reactance and resistance of the section in OHMS and total "X" and "R" to the source.
5. Calculation sheets for transformer sections shall indicate transformer kVA, secondary voltage, percent impedance, percent reactance, percent resistance, and total "X" and "R" value in OHMS at the secondary voltage to source, including The Power Company source impedance plus any primary motor contribution.

6. Calculation sheets for busway and miscellaneous devices shall provide all pertinent parameters including operating voltage, section "X" and "R" values in OHMS, and total "X" and "R" values in OHMS to the source, based on source impedance plus any motor contribution.
7. Bus summary sheets shall be provided giving consecutive bus numbers, description, voltage, "X" and "R" values in OHMS including The Power Company plus all motor contributions, symmetrical and asymmetrical short circuit amperes, X/R ration, and asymmetrical factor.
8. Motor summary sheets shall provide motor description and all pertinent motor data including subtransient reactance for each motor 10 hp and larger. Symmetrical short circuit amperes shall be given for each motor at the motor terminals.

**[SELECT BREAKER RATING METHOD]**

9. An evaluation of the adequacy of the short-circuit ratings of the electrical equipment supplied by that manufacturer. For this evaluation, circuit breakers **[shall all be fully rated]**.
10. All information shall be presented in a report form, signed and sealed by the engineer providing the analysis.

C. Protective Device Coordination Study: The Study shall include the following:

1. Time-current coordination plots shall be made on log-log sheets or equivalent software generated plots and shall graphically indicate the coordination proposed for all of the key systems. The plots shall include complete titles, one-line diagram and legend.
2. The Power Company's relay, fuse, or protective device shall be plotted with all load protective devices at the same voltage.
3. Transformer primary protective device, transformer magnetic inrush, transformer ANSI withstand points, secondary voltage fuse or circuit breaker and largest feeder fuse or circuit breaker shall be plotted at the secondary voltage. Circuit breaker curves shall include complete operating bands, terminating with the appropriate available short circuit current. Fuse curves shall be identified as either total clearing time or damage time as applicable.
4. Low voltage circuit breakers shall have instantaneous, short delay, long-time pick-up and ground fault trip settings and ground fault ampere and time delay settings identified as plotted. Sensor or monitor rating shall be stated for each circuit breaker. All regions of the circuit breaker curve shall be identified.
5. The coordination plots shall include significant motor starting characteristics and large motor protective devices.
6. Feeder circuit breakers shall have the time-damage curve of the feeder conductors plotted to indicate protection of the conductor insulation at the total clearing time of the circuit breaker or fuse. This time-damage point shall be calculated for the specific parameters of conductor insulation used, with average 3 phase RMS asymmetrical amperes as 1/2 cycle calculated using actual resistance and reactance values of the source plus all motor contributions which exist at the load end of the feeder conductors. Conductor initial temperature and conductor maximum transient temperature for short circuits as recommended by ICEA shall be indicated.
7. High voltage relays shall have coil taps, time-dial settings and pick-up settings identified as plotted. Current transformer ratios shall be stated. Relays shall be separated by a 0.45 second time margin to assure proper selectivity where feasible. The relay operating

curves shall be suitably terminated to reflect the actual maximum fault current sensed by the device.

8. A determination of settings or ratings for the overcurrent and ground fault protective devices supplied. Where necessary, an appropriate compromise shall be made between system protection and service continuity with **[service continuity] [system protection]** considered more important than system protection/service continuity. The time-current coordination analysis shall be performed with the aid appropriate software.
9. A summary tabulation shall be provided listing manufacturer and type for all overcurrent protective devices and all recommended settings of each adjustable band included in each device.
10. An evaluation of the degree of system protection and service continuity possible with the overcurrent devices supplied.
11. When main breaker is provided with setback to reduce the arc fault level both settings shall be included in the study.
12. All information shall be presented in a report form, signed and sealed by the Engineer providing the analysis.

**D. Emergency Power System Selective Coordination Study: The Study shall include the following:**

1. **Confirmation of selective coordination of all overcurrent devices associated with supplying utility and generator/UPS to emergency loads in accordance with all applicable requirements of NEC Article 100 and Paragraphs 700.27 and 701.18. Study shall be based on coordination to [0.1] [0.01] seconds. Study shall be based on the actual electrical equipment and overcurrent protective devices being submitted for the project.**
2. **Time-current coordination plots shall be made on log-log sheets or equivalent software generated plots and shall graphically indicate the coordination proposed for all of the key systems. The plots shall include complete titles, one-line diagram and legend.**
3. **Circuit breakers shall indicate manufacturer and type and have instantaneous, short delay, long-time pick-up and ground fault trip settings and ground fault ampere and time delay settings identified as plotted. Sensor or monitor rating shall be stated for each circuit breaker. All regions of the circuit breaker curve shall be identified. Circuit breaker curves shall include complete operating bands, terminating with the appropriate available short circuit current.**
4. **Fuses shall have fuse manufacturer and type indicated. Fuse curves shall be identified as either total clearing time or damage time as applicable.**
5. **High voltage relays shall indicate manufacturer and type and have coil taps, time-dial settings and pick-up settings identified as plotted. Current transformer ratios shall be stated. Relays shall be separated by a 0.45 second time margin to assure proper selectivity where feasible. The relay operating curves shall be suitably terminated to reflect the actual maximum fault current sensed by the device.**
6. **A summary tabulation shall be provided listing manufacturer and type for all overcurrent protective devices and all recommended settings of each adjustable band included in each device.**
7. **Confirmation that the proposed overcurrent protection devices, set or selected as recommended, will provide the specified selective coordination. Should the overcurrent devices proposed for the project not be capable of providing the**

**specified selective coordination, the report shall include recommendations for overcurrent protective device changes required to provide the specified coordination and calculations, plots, recommended settings as specified herein for the recommended overcurrent device changes to provide the specified selective coordination.**

8. **All information shall be presented in a report form, signed and sealed by the Engineer providing the analysis.]**

E. Arc Flash & Electrical Hazard Analysis: The Analysis shall include the following:

1. The Arc-Flash & Electrical Hazard Analysis (AFEHA) shall be performed in accordance with the requirements of NFPA 70 Section 110.16, NESC ANSI C2-2007 Section 410.A.3, IEEE Std. 1584 and OSHA 29 CFR 1910.132(d) and 1910.335.
2. The AFEHA shall:
  - a. Calculate incident energy levels and flash protection boundaries at all relevant equipment busses based on available short-circuit current, protective device clearing time and other applicable one-line diagram information.
  - b. Calculate the Minimum Arc Fault Current, Arc Flash Boundary and Arc Fault Rating ( $\text{cal/cm}^2$ ) for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - c. Identify the Arc Flash Hazard Category and risk of personnel injury as a result of exposure to incident energy released during an arc flash event for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - d. Identify the current appropriate ratings of personal protective equipment (PPE) for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - e. Establish the Flash Protection Boundary (approach limit distance) as required by NFPA 70E for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - f. Provide equipment specific environment and chemical arc-flash hazard warning label requirements per NEC Section 110.16 for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project, including all information specified to be provided on individual equipment warning labels.
  - g. Provide recommendations and methods to mitigate the hazard risk, where applicable, in order to reduce PPE requirements
  - h. All information shall be presented in a report form, signed and sealed by the engineer providing the analysis.

### 1.3 STUDY AND ANALYSIS SEQUENCE:

- A. All studies and analysis specified herein shall be completed and submitted with electrical distribution equipment submittals to allow the Engineer to review submitted electrical distribution equipment for interrupting rating, coordination and arc flash related coordination.

### 1.4 QUALITY ASSURANCE:

- A. The short circuit analysis/coordination study shall be performed by the Engineering Department of the electrical equipment supplied for the project or by a qualified engineering consultant approved in writing in advance by the Engineer.

## 1.5 SUBMITTALS:

- A. Shop Drawing submittals shall include, but not be limited to, the following:
1. Four copies of the Short-Circuit Analysis including, but not limited to:
    - a. A printout of input data, calculated results and an explanation of how to interpret the data.
    - b. A one-line diagram identifying all bus locations and the maximum available short-circuit current at each bus.
    - c. A bus-to-bus listing of the maximum available short-circuit current expressed in RMS symmetrical amperes and the X over R ratio of that fault current.
    - d. A table of specified equipment short-circuit ratings versus calculated short-circuit current values with notations of locations where are specified equipment short-circuit ratings are less or greater than required at the point of application.
    - e. An analysis of the results in which any overrating or inadequacies shall be called to the attention of the Engineer and recommendations made for improvements.
  2. Four copies of the Protective Device Coordination Study including, but not limited to:
    - a. Time-current characteristic curve drawings on log-log printouts which illustrate:
      - 1) The recommended settings for all adjustable relays, overcurrent protective devices and ground fault protective devices provided for the project.
      - 2) The key or limiting overcurrent device characteristics, load characteristics, and protection requirements affecting the settings or ratings of the overcurrent protective devices supplied.
      - 3) The degree of service continuity and system protection achieved with the overcurrent protective devices supplied.
    - b. A tabulation of the recommended settings for all adjustable relays, overcurrent protective devices and ground fault protective devices and type selections for fuse protective devices supplied.
    - c. An analysis of the results in which any inadequacies related to selective coordination shall be called to the attention of the Engineer with recommendations for improved coordination.
  3. **[Four copies of the Emergency Power System Selective Coordination Study including, but not limited to:**
    - a. **Time-current characteristic curve drawings on log-log printouts which illustrate:**
      - 1) **Compliance of the provided overcurrent protective devices with the specified selective coordination requirements.**
      - 2) **The recommended settings for all adjustable relays, overcurrent protective devices and ground fault protective devices provided for the project.**
    - b. **A tabulation of the recommended settings for all adjustable relays, overcurrent protective devices and ground fault protective devices and type selections for fuse protective devices supplied.**
    - c. **An analysis of the results in which any inadequacies related to the specified selective coordination shall be called to the attention of the Engineer with recommendations for improved coordination.]**
  4. Four copies of the arc-flash & electrical hazard analysis including, but not limited to:

- a. Minimum Arc Fault Current, Arc Flash Boundary and Arc Fault Rating ( $\text{cal}/\text{cm}^2$ ) for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - b. Arc Flash Hazard Category and risk of personnel injury as a result of exposure to incident energy released during an arc flash event for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - c. Current appropriate ratings of personal protective equipment (PPE) for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - d. The Flash Protection Boundary (approach limit distance) as required by NFPA 70 for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
  - e. Equipment specific environment and chemical arc-flash hazard warning label requirements per NEC Section 110.16 for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project, including all information specified to be provided on individual equipment warning labels.
  - f. Recommendations and methods to mitigate the hazard risk, where applicable, in order to reduce PPE requirements
5. Cut sheets and submittal information on the Arc Flash warning labels being provided.
  6. Additional information as required in Section 26 00 01, "Electrical General Provisions".

## **PART 2 - PRODUCTS**

### **2.1 ARC FLASH WARNING LABELS:**

- A. Labels: Seton Write-On Arc Flash Warning Labels or an approved equal labels with NEC and OSHA required warning information and with Arc Flash Hazard Category, minimum Personal Protection Equipment (PPE) required and Minimum Arc Rating ( $\text{cal}/\text{cm}^2$ ) clearly indicated.

## **PART 3 - EXECUTION**

### **3.1 PROTECTIVE DEVICE SELECTION AND SETTING:**

- A. Settings and Selection: Prior to project Substantial Completion, the Contractor shall set all relays, overcurrent devices and ground fault protection devices and confirm selection of fuse overcurrent devices as follows:
  1. Relays: Reset all adjustable relay settings from the factory default settings to the settings recommended in the studies specified in this section.
  2. Circuit Breakers: Reset all adjustable trip settings from the factory default settings to the settings recommended in the studies specified in this section.
  3. Ground Fault Protection Devices: Reset all adjustable device settings from the factory default settings to the settings recommended in the studies specified in this section.
  4. Fuses: Confirm that fuse types installed on the project are as recommended in the studies specified in this section.
- B. Certification: Prior to project Substantial Completion, the Contractor shall submit 4 signed copies of a document certifying that the Contractor has completed the settings and selection scope specified in Paragraph 3.1 A. to the Engineer.

### **3.2 ARC FLASH WARNING LABELS:**

- A. Installation: Arc Flash warning labels shall be securely affixed to each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch in a readily visible location in accordance with NEC and OSHA requirements. The actual calculated Minimum Arc Rating ( $\text{cal}/\text{cm}^2$ ) for that individual piece of equipment along with the associated Arc Flash Hazard Category and minimum Personal Protection Equipment (PPE) required shall be clearly indicated on each warning label

**END OF SECTION 26 05 73**