SECTION 26 0573 - POWER SYSTEMS STUDIES

Maintain Section format, including the UH master spec designation and version date in bold in the center columns of the header and footer. Complete the header and footer with Project information.

Edit and finalize this Section, where prompted by Editor's notes, to suit Project specific requirements. Make selections for the Project at text identified in bold.

This Section uses the term "Engineer." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

Delete hidden text after this Section has been edited for the Project.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. The Contractor's attention is specifically directed, but not limited, to the following documents for additional requirements:

1. The current version of the *Uniform General Conditions for Construction Contracts*, State of Texas, available on the web site of the Texas Facilities Commission.
2. The University of Houston's *Supplemental General Conditions and Special Conditions for Construction.*

1.2 DESCRIPTION OF THE WORK

A. General

1. The Load Flow, 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 power system studies shall be performed in SKM with the final native files provided to the Owner. The contractor shall perform a Power System Short Circuit Analysis, Protective Device Coordination Study, **[Emergency Power System Selective Coordination Study]** and Arc Flash and Electrical Hazard Study. These analyses and studies shall include all power distribution systems, beginning at the electric service point from the Electric Utility Company or campus utility power source **[and emergency power source(s)]** to the secondary buses of each panelboard as described hereafter. In addition, include harmonic systems and ground grid studies.
3. The electrical studies 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 Load Flow Analysis shall start at the electrical power source and terminate at each branch bus at the lowest utilization voltage. The load flow analysis shall also include a voltage drop study beginning at the electrical power source and terminate at each branch bus at the lowest utilization voltage.
5. 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 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.
6. 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.
7. **[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 devises 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.]**
8. 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 electrical equipment such as, but not limited to, switchgear, switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project. If the Arc flash energy exceeds 40 cal/cm^2, an Arc flash energy reduction option shall be reviewed and provided by the Engineer to the Owner for review and approval. The intention is to lower the energy to the extent possible, preferably less than 10 cal/cm^2.
9. 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 manufacturers 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 and phase to ground 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.
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 motors greater than 50 HP that are starting on line (DOL), starting characteristics and 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 and 0.3 for electronic relays, 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 of appropriate software. In addition, Arc flash energy reduction consideration shall be included.
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. **Microprocessor 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 0.30 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, NFPA 70E, 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. Incident energy calculations shall be provided at line and load side. Including all DC systems.
   b. Calculate the, Arc Flash Boundary and incident energy for each switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.
   c. Establish the Arc Flash Protection Boundary (Shock Protection Boundaries: Limited and restricted approach boundary) as required by NFPA 70E for each piece of electrical equipment such as, but not limited to, switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker and disconnect switch to be installed on the project.

~~d.~~ 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, disconnect switch and all DC systems to be installed on the project, including all information specified to be provided on individual equipment warning labels. Arc Flash Labels shall meet all of the following requirements per NFPA 70 and 70E. Per NFPA 70E, equipment labeling, shall contain available incident energy and the corresponding working distance only. Arc Flash Energy greater than 40 cal/cm^2 shall be color coded red with additional notes that equipment shall not be operated. Arc Flash Labels shall be submitted to the Owner for review and approval of information to be included on labels.

e. Provide recommendations and methods to mitigate the hazard risk, where applicable, in order to reduce PPE requirements. If the Arc flash energy exceeds 40 cal/cm^2, an Arc flash energy reduction option shall be provided to the Owner for review and approval. The intention is to lower the arc flash energy, if possible, to less than 10 cal/Cm^2.

f. Harmonic systems analysis: For power systems that include electronic switching devices such as adjustable speed drives (ASDs), soft starters, or uninterruptible power supply (UPS) systems, a harmonic study shall be performed. The study shall determine if the total harmonic distortion on any bus that supplies loads, other than electronically-switched devices, is more than 5 percent and does not comply with IEEE 519. The harmonic study shall also determine if any negative actions, such as the tripping of circuits or overvoltage conditions, can result due to switching of power factor correction capacitor systems. If so, corrective measures may be required (consult with the Owner).

g. Ground Grid Studies: A study shall be done during the design phase to help determine the required number and type of ground rods required to meet the desired resistance levels as identified Normally, the grounding electrode system shall have a resistance to earth of 5 ohms or less as verified by testing. Some instrument systems, especially those using intrinsically safe systems, require a resistance to earth of 1 ohm or less. A study shall be done during the design phase to verify that the required number and type of ground rods are installed to meet these resistance levels. The study shall be based on measured soil conditions or as directed by the Owner. A grounding study based on IEEE 80 and IEEE 142 shall be performed whenever a utility-fed main outdoor substation yard is in the scope of work. Calculations showing the touch and step potentials in the outdoor substation shall be submitted to the Owner.

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. All electrical studies shall be performed by the Engineering Department of the electrical equipment supplier 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 Load Flow 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 listing of the equipment regarding the normal current carrying capacity and normal current load. In addition, the voltage drop results shall be provided for every cable.
2. 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.
3. 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.
4. **[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.]

5. Four copies of all the electrical powers studies including, but not limited to:
   a. Minimum Arc Fault Current, Shock and Arc Flash Boundary and Arc Fault Rating (cal/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 Arc Flash Protection Boundary (approach limit distance) as required by NFPA 70 and NFPA 70E 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 and NFPA 70E 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
6. Cut sheets and submittal information on the Arc Flash warning labels being provided.
7. Additional information as required in Section 26 0001 “Electrical General Provisions”.
8. Contractor to provide all electronic data files (SKM, ETAP, etc.) to Owner at the conclusion of the project as part of close out documentation.

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. If the Arc flash energy exceeds 40 cal/cm^2, an Arc flash energy reduction option shall be provided to the Owner for review and approval. The intention is to lower the energy, if possible, to less than 10 cal/cm^2.

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 of electrical equipment such as, but not limited to, switchboard, distribution panel, panelboard, automatic transfer switch, enclosed circuit breaker, disconnect switch and all DC battery systems in a readily visible location in accordance with NEC and OSHA requirements.

END OF SECTION 26 0573