SECTION 26 05 73 – POWER SYSTEM STUDY

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. All sections of the project manual are directly applicable to this specification section. Should a conflict arise between specification sections or between specifications and drawings and/or code requirements, the contractor shall notify the Architect/Engineer of the conflict in writing. If direction is not provided prior to the submission of the bid, the contractor shall price the more extensive system.

1.2 SUMMARY

A. Section includes computer-based, power systems study with the following sections:

1. Overcurrent protective device coordination study to determine overcurrent protective devices and to determine overcurrent protective device settings for selective tripping.
2. Fault current study to determine the minimum interrupting capacity of circuit protective devices.
3. Arc-Flash study to determine the arc-flash hazard distance and the incident energy to which personnel could be exposed during work on or near electrical equipment.

1.3 DEFINITIONS

A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.

B. One-Line Diagram: A diagram which shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.

C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion from the system.

D. SCCR: Short-circuit current rating.

E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

1.4 ACTION SUBMITTALS

A. Product Data: For computer software program to be used for studies.

B. Other Action Submittals: Submittals shall be in digital form. Upload electronic submittals using Owner’s web-based file transfer system.

1. Power system study input data, including completed computer program input data sheets.

   a. Obtain from the Office of Physical Plant a letter listing the electrical characteristics of the service to be used in the power study. Letter shall be on PSU letterhead, signed by the OPP engineer, or shall be in an email with the engineer's official email signature.
   b. Electrical service characteristics to be included in the letter shall be:

      1) Primary and secondary voltage at the service transformer
      2) Size of the service transformer
      3) Available fault current at the primary connections of the transformer (three phase fault current and phase to ground fault current)
      4) X/R ratio of the transformer (positive sequence and zero sequence)
      5) Impedance (%Z) of the transformer
      6) Any other characteristics unique to the installation

2. Detailed Arc Flash Study Option Report.
3. Study and equipment evaluation reports; Signed, dated, and sealed by a qualified professional engineer.

   a. Submit study report for action prior to receiving final approval of the distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Owner (Project Manager (PM) and Engineering Services Electrical Group)/Engineer for preliminary submittal of sufficient study data to ensure that the selection of devices and associated characteristics is satisfactory.

4. Revised single-line diagram, reflecting field investigation results and results of power system study. This shall include the following:

   a. The single-line generated by the computer software program used for the study and documented in the report, with labels and data as indicated in section 2.2 C. of this specification.
   b. Updated CAD generated one-lines for use by Owner. At a minimum, the format should capture single-line detail (name, voltage, bus size, SCCR, circuit breaker sizes and quantities) for equipment including switchgear, switchboards, and distribution panels. Appliance panelboards should indicate name, voltage, frame size, and main type (MLO or MCB and size). Layouts must be clearly labeled and legible in 24”x36” format.

      1) Note: SCCR information shall be documented on a NON-PLOT CAD layer
      2) Layout shall be riser format, including floor level numbers. Do not include room numbers.

   c. Panelboard locations from field investigation shall be documented and labeled in CAD format on Block Plans and turned over to Owner.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For Coordination Study Specialist.

B. Product Certificates: For overcurrent protective device coordination study software (short-circuit and arc-flash hazard studies), certifying compliance with IEEE 399, IEEE1584, and NFPA 70E.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For the overcurrent protective devices to include in emergency, operation, and maintenance manuals.

1. Include the following:

a. The following parts from the Power System Study Report:

1) One-line diagram in .pdf and .dwg format per section 1.4 B. 3.b.

a) Provide one (1) full size (24”x36”), laminated hard copy of the system one-line.

2) Complete power system model in SKM format.

a) The contractor is required to provide the study project files to the Owner in electronic format.
b) Include all associated library and directory files.

3) Time-current coordination curves.
4) Arc Flash Labels.

b. Power system data.

B. Maintenance procedures according to requirements in NFPA 70E shall be provided in equipment manuals.

1.7 QUALITY ASSURANCE

A. Coordination Study Specialist Qualifications: Professional engineer in charge of performing the study and documenting recommendations, licensed in the state where Project is located and has a minimum of 5 years’ experience utilizing the program. All elements of the study shall be performed under the direct supervision and control of this professional engineer.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE DEVELOPERS

A. Software Developers: Subject to compliance with requirements, provide software by the following:

1. SKM Systems Analysis, Inc

B. Comply with IEEE 242, IEEE 399, IEEE 1584, and NFPA 70E.

C. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

D. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.

1. Optional Features:

a. Arcing faults.
b. Simultaneous faults.
c. Explicit negative sequence.
d. Mutual coupling in zero sequence.

2.2 PROTECTIVE DEVICE COORDINATION STUDY REPORT CONTENTS

A. Executive summary shall include deficiencies and recommendations as found by the study.

B. Study descriptions, purpose, basis and scope. Include case descriptions, definition of terms and guide for interpretation of the computer printout.

C. One-line diagram, showing the following:

1. Protective device designations, ampere ratings, and short-circuit (AIC) rating of equipment.
2. Cable size and lengths.
3. Transformer kilovolt ampere (kVA) and voltage ratings.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, and panelboard designations.
6. Available fault current at each piece of equipment.

D. Study Input Data: As described in "Power System Data" Article.

E. Short-Circuit Study Report: Present information in table format of report summary with nameplate and calculated values and compare with percentages.

1. Protective Device Evaluation:

a. Evaluate equipment and protective devices and compare to short-circuit ratings.

1) Where available fault current is 90% or more of the equipment’s rating, highlight row in red.
2) Where available fault current is greater than 80% of the equipment’s rating and less than 90%, highlight row in yellow.

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

c. For 600-V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2–cycle symmetrical fault current.
d. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in the standards to 1/2–cycle symmetrical fault current.
e. Verify adequacy of phase conductors at maximum three-phase bolted fault currents; verify adequacy of equipment grounding conductors and grounding electrode conductors at maximum ground-fault current.

2. Short-Circuit Study Output:

a. Low-Voltage Fault Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

1) Voltage.
2) Calculated fault-current magnitude and angle.
3) Fault-point X/R ratio.
4) Equivalent impedance.

b. Momentary Duty Report:

1) Voltage.
2) Calculated symmetrical fault-current magnitude and angle.
3) Fault-point X/R ratio.
4) Calculated asymmetrical fault current:

a) Based on fault-point X/R ratio.
b) Based on calculated symmetrical value multiplied by 1.6.
c) Based on calculated symmetrical value multiplied by 2.7.

c. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

1) Voltage.
2) Calculated symmetrical fault-current magnitude and angle.
3) Fault-point X/R ratio.
4) No AC Decrement (NACD) ratio.
5) Equivalent impedance.
6) Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on a symmetrical basis.
7) Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on a total basis.

F. Protective Device Coordination Study:

1. Report existing, where applicable, and recommended settings of protective devices, ready to be applied in the field (may be provided in table format). Use manufacturer's data sheets for recording the recommended setting of overcurrent protective devices when available.

a. Circuit Breakers:

1) Adjustable pickups and time delays (long time, short time, ground).
2) Adjustable time-current characteristic.
3) Adjustable instantaneous pickup.
4) Recommendations on improved trip systems, if applicable.

   b. Fuses: Show current rating, voltage, and class.

G. Time-Current Coordination Curves: Determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists between devices installed in series, including power utility company's upstream devices. Prepare separate sets of curves for the switching schemes/scenarios and for emergency periods where the power source is local generation. Show the following information:

   1. Device tag and title, one-line diagram with legend identifying the portion of the system covered.
   2. Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device is exposed.
   3. Identify the device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.
   4. Plot the following listed characteristic curves, as applicable:

      a. Medium- and low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
      b. Low-voltage equipment circuit-breaker trip devices, including manufacturer's tolerance bands.
      c. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
      d. Cables and conductors damage curves.
      e. Ground-fault protective devices.
      f. Motor-starting characteristics and motor damage points.
      g. The largest feeder circuit breaker in each motor-control center and panelboard.

   5. Provide adequate time margins between device characteristics such that selective operation is achieved per IEEE 242.
   6. Comments and recommendations for system improvements.

H. Arc-Flash Study Output:

   1. Interrupting Duty Report: Provide in table format based on measures taken to reduce incident energy. Provide normal, emergency, and reduced energy let-through settings for each device. Three-phase and unbalanced fault calculations, showing the following for each overcurrent device 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. Provide worst case value.
      g. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on a total basis. Provide worst case value.

   2. When OCPD setting changes are recommended based on previous section G, verify no changes to available incident energy occur. Where breaker setting changes affect the arc-flash output, document impacted values in separately labeled table.

I. 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.

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

2.3 ARC-FLASH WARNING LABELS

A. Comply with requirements in Section 26 05 53 "Identification for Electrical Systems." Produce a 3.5-by-5-inchthermal transfer label of high-adhesion polyester for each work location included in the analysis.

B. The label shall have an orange header with the wording, "WARNING, ARC-FLASH HAZARD," and shall include the following information taken directly from the arc-flash hazard analysis:

1. Location designation and fed from location
2. Nominal voltage.
3. Flash protection boundary (Restricted and Limited).
4. Incident energy.
5. Working distance.
6. Engineering report number, Engineering Company Name, revision number, and issue date.
7. Label format shall comply with samples published on the PSU OPP Design and Construction Standards web site.

C. Labels shall be machine printed, with no field-applied markings.

1. For equipment with separate “maintenance mode” settings, a separate Arc Flash label shall be installed. “Maintenance mode” labels shall be printed in blue.
2. Equipment with incident energy levels above 40 cal, a red “Danger” label shall be installed per requirements in Section 26 05 53 “Identification for Electrical Systems.”

PART 3 - EXECUTION

3.1 EXAMINATION

A. Obtain all data necessary for the conduct of the study.

1. Verify completeness of data supplied on the one-line diagram. Call any discrepancies to the attention of Owner.
2. For equipment provided that is Work of this Project, use characteristics submitted under the provisions of action submittals and information submittals for this Project.

3. For equipment that is either relocated or existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers. The qualifications of technicians and engineers shall be qualified as defined by NFPA 70E.

B. Gather and tabulate the following input data to support the short-circuit study. Comply with recommendations in IEEE 551 as to the amount of detail that is required to be acquired in the field. Field data gathering shall be under the direct supervision and control of the engineer in charge of performing the study, and shall be by the engineer or its representative who holds NETA ETT Level III certification or NICET Electrical Power Testing Level III certification approved by owner.

1. Product Data for Project's overcurrent protective devices involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
2. Power sources and ties.
3. Full-load current of all loads.
4. Voltage level at each bus.
5. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
6. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip, SCCR, current rating, and breaker settings.
7. Motor horsepower and NEMA MG 1 code letter designation.
8. Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).
9. Medium-voltage cable sizes, lengths, conductor material, and cable construction and metallic shield performance parameters.

C. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance. Devices to be coordinated are indicated on Drawings.

1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted prior to coordination study may not be used in study.

   a. This process should occur concurrently with equipment submittal reviews and prior to approval, sign-off, and purchase order of associated equipment. Coordinate with PM and Engineering Services Electrical Group as necessary.

3.2 SHORT-CIRCUIT STUDY

A. Perform study following the general study procedures contained in IEEE 399.

B. Calculate short-circuit currents according to IEEE 551.

C. Base study on the device characteristics supplied by device manufacturer.

D. The extent of the electrical power system to be studied is indicated on Drawings and noted herein.

E. Begin short-circuit current analysis at the service, extending down to the system overcurrent protective devices as follows:

1. To normal system low-voltage load buses where fault current is 10 kA or less.
2. Analysis shall extend to all panelboards included in project, as well as mechanical equipment included in the Mechanical-Electrical Coordination Schedule that have an available fault current listed.

F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

G. The calculations shall include the ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and shall apply to low- and medium-voltage, three-phase ac systems. The calculations shall also account for the fault-current dc decrement, to address the asymmetrical requirements of the interrupting equipment.

1. 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.
2. Motors supplied by VFDs shall be considered to contribute no fault, unless they are known to operate in bypass mode.

H. Calculate short-circuit duties for a three-phase bolted fault at each of the following:

1. Low-voltage switchgear.
2. Branch circuit panelboards.
3. Disconnect switches.

I. Short Circuit 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. Any application of series-rated devices shall be recertified, complying with requirements in NFPA 70.

3.3 PROTECTIVE DEVICE COORDINATION STUDY

A. Comply with IEEE 242 for calculating short-circuit currents and determining coordination time intervals.

B. Comply with IEEE 399 for general study procedures.

C. The study shall be based on the device characteristics supplied by device manufacturer.

D. The extent of the electrical power system to be studied is indicated on Drawings.

E. Begin analysis at the service, extending down to the system overcurrent protective devices as follows:

1. To normal system low-voltage load buses where fault current is 10 kA or less.

F. Transformer Primary Overcurrent Protective Devices:

1. Device shall not operate in response to the following:

a. Inrush current when first energized.
b. Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.
c. Permissible transformer overloads according to IEEE C57.96 if required by unusual loading or emergency conditions.

2. Device settings shall protect transformers according to IEEE C57.12.00, for fault currents.

G. Motor Protection:

1. Select protection for low-voltage motors according to IEEE 242 and NFPA 70.
2. Select protection for motors served at voltages more than 600 V according to IEEE 620.

H. Conductor Protection: Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and protection recommendations in IEEE 242. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary relay protection or total clearing time of the fuse. To determine temperatures that damage insulation, use curves from cable manufacturers, SKM cable data, or from listed standards indicating conductor size and short-circuit current.

I. The study shall demonstrate that the protective devices as selected and set will ensure that the minimum unfaulted load is interrupted when protective devices isolate a fault or overload anywhere in the system while satisfactory protection is provided for equipment against overloads and short circuits are interrupted as rapidly as possible.

3.4 POWER SYSTEM DATA

A. Obtain all data necessary for the conduct of the overcurrent protective device study.

1. Verify completeness of data supplied in the cable schedule and one-line diagram on Drawings. Call discrepancies to the attention of the Owner/PSU Engineering Services Electrical Group.
2. For new equipment, use characteristics submitted under the provisions of action submittals and information submittals for this Project.
3. For existing equipment, whether or not relocated obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers. The qualifications of technicians and engineers shall be qualified as defined by NFPA 70E.

B. Gather and tabulate the following input data to support coordination study. The list below is a guide. Comply with recommendations in IEEE 551 for the amount of detail required to be acquired in the field. Field data gathering shall be under the direct supervision and control of the engineer in charge of performing the study, and shall be by the engineer or its representative who is approved by owner.

1. Short-circuit current at each system bus, three phase and line-to-ground as obtained from the Short-Circuit study completed prior.
2. Maximum demands from service meters.
3. Data sheets to supplement electrical distribution system diagram, cross-referenced with tag numbers on diagram, showing the following:

a. Special load considerations, including starting inrush currents and frequent starting and stopping.

b. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.
c. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.
d. Ratings, types, and settings of utility company's overcurrent protective devices.
e. Special overcurrent protective device settings or types stipulated by utility company.
f. Time-current-characteristic curves of devices indicated to be coordinated.
g. Manufacturer, frame size, interrupting rating in amperes rms symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.
h. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.
i. Panelboards, switchboards, motor-control center ampacity, and SCCR in amperes rms symmetrical.
j. Identify series-rated interrupting devices for a condition where the available fault current is greater than the interrupting rating of the downstream equipment. Obtain device data details to allow verification that series application of these devices complies with NFPA 70 and UL 489 requirements.

3.5 ARC-FLASH HAZARD ANALYSIS

A. Comply with NFPA 70E and its Annex D for hazard analysis study.

B. Calculate maximum and minimum contributions of fault-current size for normal, emergency, and maintenance mode settings.

1. The minimum calculation shall assume that the utility contribution is at a minimum and shall assume no motor load.
2. The maximum calculation shall assume a maximum contribution from the utility and shall assume motors to be operating under full-load conditions.

C. Calculate the arc-flash protection boundary and incident energy at locations in the electrical distribution system where personnel could perform work on energized parts.

D. Include medium- and low-voltage equipment locations, except equipment rated 240 VAC or less fed from transformers less than 125 kVA.

E. Safe working distances shall be specified for calculated fault locations based on the calculated arc-flash boundary, considering incident energy of 1.2 cal/sq.cm.

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

1. Fault contribution from induction motors should not be considered beyond three to five 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 three per unit after 10 cycles).

G. Arc-flash computation shall include both line and load side of a circuit breaker as follows:

1. When the circuit breaker is in a separate enclosure.
2. When the line terminals of the circuit breaker are separate from the work location.

H. Base arc-flash calculations on actual overcurrent protective device clearing time. Cap maximum clearing time at two seconds based on IEEE 1584, Section B.1.2.

I. Report shall include recommendations of reducing fault current levels and enhancing worker safety.

1. Provide arc-flash reduction maintenance settings if specified.

3.6 LABELING

A. Apply arc-flash label(s) as required for 600-V ac, 480-V ac, and 208-V ac panelboards and disconnects and for each of the following locations:

1. Panelboard.
2. Transformers (secondary compartment).
3. Disconnects and enclosed circuit breakers.

B. Any equipment excluded from study by IEEE 1584 should receive, at a minimum, a generic arc flash warning label. Review approach with PSU Engineering Services Electrical Group prior to performing calculations.

3.7 APPLICATION OF WARNING LABELS

A. Prior to final printing of adhesive type labels. The study specialist must print paper copies of all labels for approval by Engineering Services. The study specialist shall field install (tape up) the printed paper copies. Once paper copies have been installed, the study specialist shall have the labels verified by PSU Electrical Integrity crew. Upon approval by PSU Electrical Integrity crew and Engineering Services Electrical Group, the study specialist shall print the final adhesive labels and field install in same locations as the printed labels.

B. Install the arc-fault warning labels under the on-site supervision and control of the Arc-Flash Study Specialist.

END OF SECTION