SECTION 26 05 71 - 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.

1.2 SUMMARY

A. Section includes a computer-based power system one-line model, fault current analysis, overrcurrent setting/trip coordination, and arc flash study including gathering power system field data and submitting study reports to determine:

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

B. The Contractor shall be responsible to fully coordinate all overcurrent protective devices within the scope of work, unless indicated otherwise.

C. The extent of the electrical power system to be studied is indicated on Drawings; unless otherwise noted, scope shall include all new protective devices and equipment, and in renovations and additions their next higher and lower existing devices and 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. Pre-Installation Submittal: Included with major distribution equipment submittal, shall be a preliminary study report prepared using actual submitted equipment and overcurrent protective devices.

1. Refer to “Report Content” articles below for submittal requirements.
2. Feeder lengths shall be based on actual Contractor take-offs, using typical minimum lengths is not acceptable.

3. Preliminary submittal shall include copy of proposed flash warning labels.

B. Post-Installation Submittal: Up to 30 days prior to Substantial Completion, Contractor shall submit an updated report.

1. Updated report shall include actual equipment installed and measured feeder lengths.
2. Copy of updated proposed flash warning labels shall also be included.
3. After Engineer approval of post-installation report Contractor shall generate and install adhesive flash warning labels.
4. All study and equipment evaluation reports; signed, dated, and sealed by a qualified professional engineer study specialist.

1.5 CLOSEOUT SUBMITTALS

A. A copy of the final corrected Study shall be included with the Owner's Operations & Maintenance Manuals.

1.6 QUALITY ASSURANCE

A. Study Specialist Qualifications: Professional engineer in charge of performing the study and documenting recommendations, licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional engineer.

B. Computer Software:

1. SKM Power Tools
2. ESA Easy Power

C. Comply with IEEE 242, 399, 551, 1584, and NFPA 70E.

PART 2 - POWER SYSTEM STUDY PROCEDURES

2.1 EXAMINATION

A. This article lists data needed to conduct the study. Contractor is responsible for gathering all data not included in the one-line drawings that are part of the Contract Documents.

B. 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 Architect and Engineer.
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. 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.
4. For relocated equipment and that which is 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.

2.2 INPUT DATA

A. Gather and tabulate the following input data to support the power system study. Comply with recommendations in IEEE 551, IEEE 1584, and NFPA 70E 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.

1. Product Data for overcurrent protective devices specified in other Sections and 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. Electrical power utility impedance at the service.
3. Power sources and ties.
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 and available range of settings, SCCR, current rating, and breaker settings.
7. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
8. Busway manufacturer and model designation, current rating, impedance, lengths, and conductor material.
9. Motor horsepower and NEMA MG 1 code letter designation.
10. Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).
11. 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.

   a. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.
   b. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.
   c. Generator 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. Panelboards, switchboards, motor-control center ampacity, and SCCR in amperes rms symmetrical.

2.3 SHORT CIRCUIT STUDY PROCEDURE

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.

E. All equipment depicted on electrical distribution riser diagram, as well as all motors 30 horsepower and larger, shall be included in system model. Fault contribution to system shall be based on available fault current on secondary of service transformer as provided by utility company, or other fault current source(s), whichever is largest.

F. Begin short-circuit current analysis at the service, extending down to all the system overcurrent protective devices.

G. 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.

H. The calculations shall include the ac fault-current decay from induction motors, synchronous motors, and asynchronous generators 30 horsepower and larger, 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.

I. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault at each of the following:

1. Electric utility's supply termination point.
2. Incoming switchgear.
3. Unit substation primary and secondary terminals.
4. Low-voltage switchgear & switchboards.
5. Motor-control centers.
6. Motor control panels (Elevators, HVAC, etc).
7. Standby generators and automatic transfer switches.
8. Distribution & branch circuit panelboards.
9. Disconnect switches.

2.4 OVERCURRENT PROTECTIVE DEVICE STUDY PROCEDURE

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. 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.

E. Motor Protection:

1. Select protection for low-voltage motors according to IEEE 242 and NFPA 70.

F. 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 or from listed standards indicating conductor size and short-circuit current.

G. Generator Protection: Select protection according to manufacturer's written recommendations and to IEEE 242.

H. 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.

I. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault and single line-to-ground fault at each of the following:

1. Electric utility's supply termination point.
2. Switchgear.
3. Unit substation primary and secondary terminals.
4. Low-voltage switchgear.
5. Motor-control centers.
6. Standby generators and automatic transfer switches.
7. Distribution & branch circuit panelboards.

J. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to short-circuit ratings.
2. Adequacy of switchgear, motor-control centers, and panelboard bus bars to withstand short-circuit stresses.

2.5 ARC FLASH STUDY PROCEDURES

A. Comply with IEEE 1584, and NFPA 70E and its Annex D for hazard analysis study.

B. Preparatory Studies:

1. Short-Circuit Study Section 2.3
2. Protective Device Coordination Study Section 2.4

C. Calculate maximum and minimum contributions of fault-current size.

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.

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

E. Include medium- and low-voltage equipment locations, except equipment rated 240-V ac or less with an available short-circuit current less than 2 kA as determined by the short-circuit study.

F. 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.

G. 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).

H. 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.

I. 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.

PART 3 – POWER SYSTEM STUDY DELIVERABLES

3.1 REPORT CONTENT

A. Executive summary.

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 and ampere ratings depicted on the electrical distribution riser diagram.
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.

D. The overcurrent/ground fault setting coordination shall create a set of time-current curves depicting successive breakers and fuses for each unique distribution system branch. Coordination shall be to 0.06 seconds, unless the AHJ requires 0.01 seconds.

E. Comments and recommendations for system improvements, where study results fail to meet design intent, specified requirements or industry standards.

F. Study Input Data: As described in Section 2.2.

G. Protective Device Evaluation:

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

2. Tabulations of circuit breaker, fuse, and other protective device ratings versus calculated short-circuit duties.
3. For 600-V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.
4. Verify adequacy of phase conductors at maximum three-phase bolted fault currents; Ensure that short-circuit withstand ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.

H. Short-Circuit Study Output:

1. The fault current analysis portion of the report shall include a print out from the software listing the available three-phase, Line-Line, and Line-Ground fault current at each piece of equipment and highlight exceeded equipment ratings.
2. Low-Voltage Fault Report: Three-phase, Line-Line, and Line-Ground fault calculations, showing the following for each overcurrent device location:
    a. Voltage.
    b. Calculated fault-current magnitude and angle.
    c. Fault-point X/R ratio.
    d. Equivalent impedance.

I. Protective Device Coordination Study Ouput:

1. Report recommended settings of protective devices, ready to be applied in the field. 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.

J. 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 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. Power utility's overcurrent protective device.
    b. low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
    c. Low-voltage equipment circuit-breaker trip devices, including manufacturer's tolerance bands.
    d. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
    e. Cables and conductors damage curves.
    f. Ground-fault protective devices.
    g. Motor-starting characteristics and motor damage points.
    h. Generator short-circuit decrement curve and generator damage point.

i. 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.
6. Comments and recommendations for system improvements.

K. Arc-Flash Study Output:

1. Incident Energy and Flash Protection Boundary Calculations:
   a. Arcing fault magnitude.
   b. Protective device clearing time.
   c. Duration of arc.
   d. Arc-flash boundary.
   e. Working distance.
   f. Incident energy.
2. Summary narrative of recommendations including overcurrent trip setting adjustments for arc-flash energy reduction to Owner’s standard protection ratings.

3.2 ARC-FLASH WARNING LABELS

A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for self-adhesive equipment labels. Produce a 3.5-by-5-inch (76-by-127-mm) self-adhesive equipment label 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, and comply with NFPA 70E:

1. Location designation.
2. Nominal voltage.
3. Flash protection boundary.
4. Hazard risk category.
5. PPE required.
6. Incident energy.
7. Working distance.
8. Engineering report number, revision number, and issue date.

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

D. Apply one arc-flash label for 600-V ac, 480-V ac, and applicable 208-V ac panelboards and disconnects and for each of the following locations, or as required by Owner’s standard:

1. Motor-control center.
2. Low-voltage switchboard.
3. Switchgear.
4. Control panel.

E. Install the arc-fault warning labels under the direct supervision and control of the Study Specialist.

3.3 FIELD ADJUSTING

A. Make minor modifications to equipment as required to accomplish compliance with short-circuit, protective device coordination, and arc flash studies.

END OF SECTION 26 05 71