READ THIS FIRST

Notice to the Design Engineer, this document is part of Facilities and Infrastructure standards for Electrical Systems. Designers are advised to NOT use this template (*.doc) document as part of any project contract documents. Designers shall use the Port of Seattle MasterSpec specifications from the following link:

https://www.portseattle.org/page/guide-specifications.

Designers shall edit the corresponding Port's MasterSpec specification to meet the F&I Electrical Standard outlined in this specification. Note that Port's MasterSpec specifications contain specifications and languages for both Aviation and Maritime Divisions. F&I Standards are strictly for Aviation Division, and any Maritime related specs or languages should be removed from the project specifications.

Power system studies must be performed by the engineer of record. This section shall not be used as a specification, as all material included in this section is to be provided by the engineer of record.

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. Coordinate with F&I at the beginning of the project to determine which studies are required. Obtain information on existing conditions that can be used for the study.
   1. Power systems studies shall be performed using EasyPower software. Other software may be used with F&I permission only.

B. Section includes computer-based studies to determine the following:

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

C. Provide Arc Flash, Short Circuit Current and Overcurrent Protective Device Coordination study for the electrical distribution system as follows:

1. All new switchgear, switchboards, distribution panels, load centers, branch circuit panels, motor control centers, PDUs, UPS units, ATSs and transformers;

D. Existing switchgear, switchboards, distribution panels, load centers branch circuit panels, motor control centers, PDUs, UPS units, ATSs and transformers impacted by project and where no existing arc flash, short circuit or coordination data is available, or where modifications occur upstream, either to upstream distribution equipment or to upstream feeders.ARC-FLASH STUDY AND WARNING LABELS

1. Where an arc flash study is performed on existing equipment, existing short circuit and protective device coordination study data may be used for the arc flash study.
2. If an existing up-to-date current short-circuit and protective device coordination study is not available, perform a short circuit and protective device coordination study for the electrical distribution system before performing the Arc Flash Hazard Arc Flash Study shall consider all operating scenarios during normal conditions alternate operations, emergency power conditions, and any other operations, which could result in maximum arc flash hazard. The label shall list the maximum incidental energy calculated and the Scenario number and description on the label. The following is a list of the known operating scenarios:
    a. Normal Utility Power
    b. Emergency Generator Power
    c. Bus Tie Breakers open
    d. Bus Tie Breakers closed
    e. UPS Power
3. Comply with requirements in Section 260553 "Identification for Electrical Systems." Produce a 3.5-by-5-inch thermal transfer label of high-adhesion polyester for each work location included in the analysis.
4. The OSHA approved 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:
    a. Location designation.
    b. Nominal voltage.
    c. Flash protection boundary.
    d. Hazard risk category.
    e. Incident energy.
    f. Working distance.
    g. Engineering report number, revision number, and issue date.
    h. Space for POS Representative initial to indicate acceptance.
5. Labels shall be machine printed, with no field-applied markings besides initial of POS representative.
6. Arc Flash warning labels shall be provide for the following equipment:
    a. Switchgear
    b. Switchboards
    c. Distribution boards
    d. Panelboards
    e. Motor Control Centers
    f. PDUs
    g. ATS

h. Transformers

7. Equipment fed by transformers rated 125kVA or less with a secondary voltage of 240V or less is considered to be Hazard Risk Category 0 by NFPA 70E. Labels shall be provided for such equipment indicating Hazard Risk Category, but this equipment does not need to be included in the arc flash study.

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: Submit the following after the approval of system protective devices submittals. Submittals shall be in paper and digital form (Microsoft Office format).

1. Power systems study input data, including completed computer program input data sheets.
2. Study and equipment evaluation reports.
3. Arc flash, short circuit and overcurrent protective device coordination study report; signed, dated, and sealed by a qualified professional engineer.
   a. Submit study report to POS AV F&I prior to receiving final approval of the distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that the selection of devices and associated characteristics is satisfactory.
4. Arc Flash draft report shall be submitted to POS AV F&I prior to printing the arc flash hazard labels. The draft report shall include copies of the proposed labels in electronic format, preferably .pdf.
5. For existing equipment, the Arc Flash study and approved labels shall be complete prior to bid.

6. For new equipment, the Arc Flash study shall be updated upon project completion using as-built electrical product and system information.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For Engineer of Record.

B. Product Certificates:

1. For short circuit and overcurrent protective device coordination study software, certifying compliance with IEEE 399.
2. For arc-flash hazard analysis software, certifying compliance with IEEE 1584 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 Protective Device Coordination Study Report:
      1) One-line diagram.
      2) Protective device coordination study.
      3) Time-current coordination curves.
   b. Power system data.
2. Maintenance procedures according to requirements in NFPA 70E shall be provided in the equipment manuals.

B. Power System Equipment Database (PSDB) shall be provided to the owner at the completion of the study. The database shall contain and list all electrical equipment used in the study and the results of the short circuit, protective device study, and arc flash study. The data base shall have the minimum features and functions:

1. Equipment Nameplate Data and available fault current for the equipment listed below:
   a. ATS
   b. Circuit Breakers
   c. Motor Control Centers
   d. Bus Duct Runs
   e. Relays
   f. Transformers
   g. Conductors
   h. Control Panels
   i. Fuses
   j. Motor Starters
   k. Panelboards
   l. Switchboards
   m. Switchgear

n. Disconnect Switches
o. Generators
p. Motors > 50HP
q. PDUs
r. VFDs
s. Utility Data
t. Other equipment as identified by POS or engineer of record.

2. The equipment nameplate data shall include a minimum of the following information:
   a. Manufacturer
   b. Type
   c. Voltage
   d. Amperage
   e. kVA
   f. HP
   g. Size and Length (conductor)
   h. # per phase (conductor)
   i. RLA & LRA (motor)
   j. NEMA code (motor)
   k. Frame Size
   l. Trip
   m. Sensor
   n. Breaker and Relay Settings
   o. Impedance (generators and transformers)
   p. Winding Connections (transformers)
   q. Temperature rating
   r. Short Circuit Rating
   s. Withstand rating
   t. Date of manufacture
   u. Weight (transformers)
   v. Catalog number and serial number

C. Power system model in EasyPower shall be delivered to POS Facilities and Infrastructure upon project completion.
   1. If alternate power study software is used, coordinate study elements with F&I.

1.7 QUALITY ASSURANCE

A. Studies shall use SKM PowerTools, EasyPower, ETAP, or approved equal computer software package. All sections of the study must be performed with same software package. Manual calculations are unacceptable. Use of NFPA 70E Task tables is not allowed to determine AF Hazard Category except with AV F&I approval on a node-by-node basis.

B. The study shall be performed by the engineer of record for the project. The engineer shall be a Registered Professional Electrical Engineer licensed in the state of Washington who has at least ten (10) years of experience and specializes in performing power system studies. All elements of the study shall be performed under the direct supervision and control of this professional engineer.

C. AV F&I representative will review and approve the calculations and will install the labels.

PART 2 - PRODUCTS

2.1 POWER SYSTEM STUDY REPORT CONTENTS – GENERAL

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. All electrical equipment and wiring to be protected, with locations clearly indicated where fault current and arc flash will be calculated.
2. Protective device designations and ampere ratings.
3. Cable size, quantity of sets, and lengths.
4. Transformer kilovolt ampere (kVA) and voltage ratings.
5. Motor and generator designations and kVA ratings.
6. Switchgear, switchboard, motor-control center, and panelboard designations.

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

2.2 PROTECTIVE DEVICE SHORT CIRCUIT AND COORDINATION STUDY REPORT CONTENTS

A. Short-Circuit Study:

1. Low-Voltage Fault Report: Three-phase and unbalanced 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.
2. Momentary Duty Report: 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. Calculated asymmetrical fault currents:
      1) Based on fault-point X/R ratio.
3. Interrupting Duty Report: 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. Equivalent impedance.

4. Protective Device Evaluation:
   a. Evaluate equipment and protective devices and compare to short-circuit ratings.
   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 currents. Ensure that short-circuit withstand ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.

B. Protective device short circuit and coordination study input data, case descriptions, and fault-current calculations including a definition of terms and guide for interpretation of the computer printout.

C. Comments and recommendations for system improvements, where needed.

D. Short Circuit Study Output:

1. Low-Voltage Fault Report: Three-phase and unbalanced 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.
2. Momentary Duty Report: 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. Calculated asymmetrical fault currents:
      1) Based on fault-point X/R ratio.
3. Interrupting Duty Report: 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. Equivalent impedance.

E. Protective Device Coordination Study:

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. Phase and Ground Relays:
      1) Device tag.
      2) Relay current transformer ratio and tap, time dial, and instantaneous pickup value.
      3) Recommendations on improved relaying systems, if applicable.
   b. 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.
   c. Fuses: Show current rating, voltage, and class.

F. 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. Medium-voltage equipment overcurrent relays.
   c. Medium- and low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
   d. Low-voltage equipment circuit-breaker trip devices, including manufacturer's tolerance bands.
   e. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
   f. Cables and conductors damage curves.
   g. Ground-fault protective devices.
   h. Motor-starting characteristics and motor damage points.
   i. Generator short-circuit decrement curve and generator damage point.
   j. The largest feeder circuit breaker in each motor-control center and panelboard.
   k. Series rating on equipment allows the application of two series interrupting devices for a condition where the available fault current is greater than the interrupting rating of the downstream equipment. Both devices share in the interruption of the fault and selectivity is sacrificed at high fault levels. Maintain selectivity for tripping currents caused by overloads.

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

2.3 ARC FLASH STUDY REPORT CONTENTS

A. Short-Circuit Study Output:

1. Interrupting Duty Report: 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.

B. Incident Energy and Flash Protection Boundary Calculations: Provide summary report for each device in study, with list of all “Dangerous” locations (using maximum calculated energy levels) where the incident energy level is 40 cal/cm^2, above Hazard Risk Category 4. The report shall list the following items,

1. Bus Name
2. Upstream Protective Device Name, Type, and Settings
3. Bus Line-to-Line Voltage
4. Bus Bolted Fault Current
5. Protective Device Bolted Fault Current
6. Arcing fault current magnitude.
7. Protective device trip/delay time.
8. Breaker Opening Time.
9. Duration of arc.
10. Arc-flash boundary.
11. Working distance.
12. Incident energy.
13. Hazard risk category.

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

PART 3 - PROCEDURE

3.1 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 one-line diagram on Drawings. Call discrepancies to the attention of Architect.
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.
4. Existing Equipment Data will be provided by the Port.

B. Gather and tabulate the following input data to support coordination study. The list below is a guide. Comply with recommendations in IEEE 241 and 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 holds NETA certification acceptable to AHJ and Port of Seattle.

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. Assume infinite bus for utility power supply.
3. Power sources and ties.
4. Short-circuit current at each system bus, three phase and line-to-ground.
5. Full-load current of all loads.
6. Voltage level at each bus.
7. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
8. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
9. 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.
10. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
11. For relays, provide manufacturer and model designation, current transformer ratios, potential transformer ratios, and relay settings.
12. Maximum demands from service meters.
13. Busway manufacturer and model designation, current rating, impedance, lengths, and conductor material.
14. Motor horsepower and NEMA MG 1 code letter designation.
15. Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).
16. Medium-voltage cable sizes, lengths, conductor material, and cable construction and metallic shield performance parameters.
17. 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. Generator thermal-damage curve.
e. Ratings, types, and settings of utility company's overcurrent protective devices.
f. Special overcurrent protective device settings or types stipulated by utility company.
g. Time-current-characteristic curves of devices indicated to be coordinated.
h. 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.
i. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.
j. Panelboards, switchboards, motor-control center ampacity, and SCCR in amperes rms symmetrical.
k. 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.

3.2 SHORT CIRCUIT STUDY

A. 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.

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. Obtain electrical power utility impedance at the service.
3. Power sources and ties.
4. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
5. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
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. 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. Cable sizes, lengths, number, conductor material and conduit material (magnetic or nonmagnetic).

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

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

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

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

F. 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.

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 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 and distribution panels.
5. Motor-control centers.
6. Control panels.
7. Standby generators and automatic transfer switches.
8. Branch circuit panelboards.
9. Disconnect switches.

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

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. 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.

H. 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.

I. 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.

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

K. 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.

L. 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. Branch circuit panelboards.

M. 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.

3.4 ARC FLASH HAZARD ANALYSIS

A. The study shall be in accordance with latest applicable NFPA 70E, OSHA 29-CFR, Part 1910 Sub part S, IEEE 1584, and NESC Standards. The study must be performed using IEEE 1584 for equipment rated 50 to 15 kV and NESC for equipment rated above 15 kV.

B. Use the short-circuit study output and the overcurrent protective device coordination study output or field-verified settings of the overcurrent devices.

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.

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 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.

3.5 LOAD-FLOW AND VOLTAGE-DROP STUDY

A. Perform a load-flow and voltage-drop study to determine the steady-state loading profile of the system. Analyze power system performance two times as follows:

1. Determine load-flow and voltage drop based on full-load currents obtained in "Power System Data" Article.
2. Determine load-flow and voltage drop based on 80 percent of the design capacity of the load buses.
3. Prepare the load-flow and voltage-drop analysis and report to show power system components that are overloaded, or might become overloaded; show bus voltages that are less than as prescribed by NFPA 70.

3.6 MOTOR-STARTING STUDY

A. Perform a motor-starting study to analyze the transient effect of the system's voltage profile during motor starting. Calculate significant motor-starting voltage profiles and analyze the effects of the motor starting on the power system stability. Include motors rated 50 HP and greater in study.

B. Prepare the motor-starting study report, noting light flicker for limits proposed by IEEE 141 and IEEE 519, and voltage sags so as not to affect the operation of other utilization equipment on the system supplying the motor.

3.7 FIELD ADJUSTING

A. Adjust relay and protective device settings according to the recommended settings provided by the coordination study. Field adjustments shall be completed by the engineering service division of the equipment manufacturer under the Startup and Acceptance Testing contract portion.

B. Make minor modifications to equipment as required to accomplish compliance with short-circuit and protective device coordination studies.

C. Testing and adjusting shall be by a full-time employee of the Field Adjusting Agency, who holds NETA certification acceptable to AHJ and Port of Seattle.

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters. Perform NETA tests and inspections for all adjustable overcurrent protective devices.

3.8 LABELING

A. Apply one arc-flash label for 12,470-Vac, 4160-Vac, 600-V ac, 480-V ac, and applicable 208-V ac panelboards and disconnects and for each of the following locations:

1. Motor-control center.
2. Low-voltage switchboard.
3. Switchgear.
4. Medium-voltage switch.
5. Power Center.
6. Control panel.

B. Labels shall be printed in color and shall be moisture proof, adhesive backed. Labels for outdoor equipment shall be vinyl and UV resistant to avoid fading.

C. APPLICATION OF WARNING LABELS

1. Arc Fault warning labels shall be furnished by engineer and installed by POS AV F&I and Maintenance.

3.9 DEMONSTRATION

A. Engage the Coordination Study Specialist to train Owner's maintenance personnel in the following:

1. Acquaint personnel in the fundamentals of operating the power system in normal and emergency modes.
2. Hand-out and explain the objectives of the coordination study, study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpreting the time-current coordination curves.
3. Adjust, operate, and maintain overcurrent protective device settings.

END OF SECTION 260573