SPECIFICATIONS - DETAILED PROVISIONS
Section 16040 – Short-Circuit/Coordination Study and Arc-Flash Hazard Study

CONTENTS

SECTION 16040
SHORT-CIRCUIT/COORDINATION STUDY AND ARC-FLASH HAZARD STUDY

PART 1 - GENERAL

1.01 SUMMARY

A. Contractor shall provide a Short-Circuit and Protective Device Evaluation Study, a Protective Device Coordination Study, and an Arc-Flash Hazard Study, as specified herein.

B. The studies shall be performed for the purposes of estimating the worst case available short-circuit current values and arc-flash incident energy. The studies shall be generated based on information obtained from electrical equipment submittals, actual conductor sizes and lengths for all feeders, utility short circuit current value at the main service switchboard, and information obtained from field reconnaissance of existing equipment/material (if applicable).

C. Contractor shall obtain the short circuit current value at the main service switchboard for the specific project location from the utility. Contractor shall bear all costs associated with obtaining the available short circuit current value.

D. Contractor shall adjust all required protective device settings based on the results of the Protective Device Coordination Study and Arc-Flash Hazard Study.

E. Contractor shall install Arc-Flash and Shock Hazard labels on all electrical equipment, as specified herein.

1.02 DESCRIPTION OF THE WORK

A. <u>Short-Circuit and Protective Device Evaluation Study</u>

1. Contractor shall provide a Short-Circuit and Protective Device Evaluation Study to verify the proposed equipment ratings and protective device ratings.

2. Unless specified otherwise, the scope of the study shall include all proposed distribution equipment supplied under this Contact, as well as all directly affected existing distribution equipment at the District's facility. The study shall include all portions of the existing and proposed electrical distribution system from the electric utility power source(s) and emergency power source(s) down to and including each switchboard, distribution panel, transfer switch (automatic or manual), motor control center, variable frequency drive, distribution panelboard, branch circuit panelboard, busway, enclosed circuit breaker and fused disconnect switch.

B. <u>Protective Device Coordination Study</u>

1. Contractor shall provide a Protective Device Coordination Study to determine and coordinate the selective tripping of protective devices for the proposed equipment.

2. Unless specified otherwise, the scope of the study shall include all proposed distribution equipment supplied under this Contact, as well as all directly affected existing distribution equipment at the District's facility. The study shall include all portions of the existing and proposed electrical distribution system from the electric utility power source(s) and emergency power source(s) down to and including the smallest adjustable trip circuit breaker and fused disconnect switch in the system.

C. <u>Arc-Flash Hazard Study</u>

1. Contractor shall provide an Arc-Flash Hazard Study to determine potential arc-flash incident energies, arc-flash boundaries, shock hazard boundaries; required personal protective equipment (PPE) for all energized electrical equipment; and arc-flash and shock hazard warning labels.

2. Unless specified otherwise, the study shall include all electrical circuits from the electric utility power source(s) and emergency power source(s) to and including all electrical equipment and panelboards rated 208 V and greater.

3. Wherever possible, the proposed electrical equipment shall be designed, manufactured, and supplied to limit the potential arc-flash incident energy to 8 cal/sq cm or less (PPE Category 2). The firm performing the studies

shall coordinate with Contractor, the District, and the electrical equipment manufacturers to assist in achieving this requirement.

D. Field Verification

Contractor shall provide the services of an independent testing consultant or firm performing the studies to field verify that all protective devices are set in accordance with the accepted short-circuit/coordination study requirements and recommendations. In addition, the consultant or firm shall verify that all arc-flash and stock hazard labels have been installed. _NETA ATS testing is required for the complete electrical system.

1.03 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all Sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Division 11 – Equipment

2. Division 16 – Electrical

1.04 REFERENCE STANDARDS AND CODES

Unless specified otherwise, all calculations, analyses, and studies, including application of same to equipment and settings shall meet or exceed the applicable requirements of the following standards and codes (latest edition):

A. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1. IEEE 141 – Recommended Practice for Electric Power Distribution for Industrial Plants

2. IEEE 142 – Recommended Practice Grounding of Industrial and Commercial Power Systems

3. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings

4. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

5. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis

6. IEEE 551 – Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems

7. IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems

8. IEEE 1584 - Guide for Performing Arc-Flash Hazard Calculations.

B. American National Standards Institute (ANSI):

1. ANSI C37.010 – Standard Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

2. ANSI C37.13 – Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

3. ANSI C37.41 – Standard Design Tests for High-Voltage Fuses, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links and Accessories Used with These Devices.

4. ANSI C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

C. Code of Federal Regulations:

1. CFR 29, Subpart R, Part 1910.269, Occupational Safety and Health Standards - Electric Power Generation, Transmission, and Distribution.

2. CFR 29, Subpart S, Part 1910.301 through 1910.399, Occupational Safety and Health Standards - Electrical.

D. The National Fire Protection Association (NFPA):

1. NFPA 70 - National Electrical Code, latest edition

2. NFPA 70E – Standard for Electrical Safety in the Workplace

1.05 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. Computer Software Information

Submit product literature/brochure for computer software to be utilized for the studies. Submit computer software statement of compliance with IEEE, ANSI, and NFPA 70E standards and requirements.

B. Qualification Information

Submit qualification information for firm and individual(s) specified in Part 1.06 herein.

C. Utility Information

Submit letter from utility with available short circuit current value at the main service switchboard. As a minimum, the utility letter shall include the following: project address, service voltage and configuration, main service switchboard amperage, short circuit current (3-phase and phase-ground), 3-phase and phaseground X/R ratios, service transformer kVA and impedance, and service conductor size, number, and length.

D. Study Results and Report

The results of the Short-Circuit and Protective Device Evaluation Study, Protective Device Coordination Study, and Arc-Flash Hazard Study shall be summarized in a well-organized, comprehensive report. The report shall address all study requirements specified in Part 2 herein. A sample outline for the report is provided below:

1. Section 1 - Executive Summary

2. Section 2 - Short-Circuit and Protective Device Evaluation Study

    2.1 Short-Circuit Analysis Objectives
    2.2 System Modeling
    2.3 Short-Circuit Results
    2.4 Equipment, Material, and Protective Device Evaluation

3. Section 3 - Protective Device Coordination Study

    3.1 General Description and Protection Philosophy
    3.2 Codes and Standards
    3.3 Coordination Objectives
    3.4 Coordination Results
    3.5 Coordination Recommendations
    3.6 Time-Current Characteristic Plots

4. Section 4 - Recommended Protective Device Settings

5. Section 5 - Short-Circuit Analysis Computer Reports

    5.1 Report Interpretation
    5.2 Short-Circuit Input Data Report
    5.3 Short-Circuit Analysis Results Report - Utility Source
    5.4 Short-Circuit Analysis Results Report - Generator Source
    5.5 Short-Circuit Analysis Results Report - Single-Phase

6. Section 6 - Arc-Flash Hazard Study

    6.1 General Description
    6.2 Analysis Procedure
    6.3 Arc-Flash Analysis Results
    6.4 Arc-Flash Analysis Recommendations

6.5 Arc-Flash Labels and Location Drawings

7. Section 7 - Single Line Diagrams

7.1 Power System Study Diagram
7.2 Reference Drawing Single Line Diagrams

Unless specified otherwise, Contractor shall provide all computer software project study files to the District in electronic format. In addition, a copy of the computer analysis software viewer program shall be provided with the electronic project files, to allow the District to review all aspects of the project and print single line diagrams, arc-flash labels, etc.

E. <u>Coordination of Studies and Equipment Submittals</u>

The Short-Circuit and Protective Device Coordination Studies shall be submitted to the District prior to receiving final acceptance of the related equipment shop drawings and prior to equipment fabrication. If formal completion of the studies may cause delay in equipment fabrication and delivery, approval from the District may be obtained for preliminary submittal of sufficient study data to ensure that the proposed equipment ratings and protective device selection/characteristics will be satisfactory.

1.06 QUALIFICATIONS

A. The firm and individual(s) performing the specified studies shall be experienced in the application of computer software used for power system studies, and shall have performed studies of similar magnitude on electrical systems using similar equipment and devices.

B. The short-circuit, protective device coordination, and arc-flash hazard studies shall be conducted under the direct supervision and control of a Registered Professional Electrical Engineer skilled in performing and interpreting the power system studies. Each study report shall be signed and stamped by the Registered Professional Electrical Engineer.

C. Credentials and background of the firm and individual(s) performing the study shall be submitted to the District for approval prior to commencing the work. A minimum of five (5) years of experience in power system analysis is required for the engineer in charge of the project.

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Short-Circuit and Protective Device Evaluation Study, Protective Device Coordination Study, and Arc-Flash Hazard Study shall be performed by the same entity.

B. The studies shall be submitted to the District prior to fabrication of any electrical distribution equipment. District's written approval will be required prior to equipment fabrication.

C. Contractor shall be responsible for supplying pertinent electrical system information for proposed equipment/material and existing equipment/material (if applicable).

D. The studies shall include all portions of the electrical system including the electric utility power source and emergency power sources, and contributions from inductive loads on the medium voltage (if applicable) and low voltage (480V) distribution system.

E. All induction motors greater than 50 HP shall be included individually with associated starters and feeder impedance. Unless specified otherwise, all induction motors 50 HP or less and fed from the same bus may be grouped together.

F. Normal system connections and those which result in maximum fault conditions shall be adequately evaluated in the studies.

G. The studies shall be performed using the latest version of the SKM Systems Analysis software (no substitutes). Software shall comply with all applicable IEEE, ANSI, and NFPA 70E standards and requirements.

2.02 DATA COLLECTION

A. Contractor shall be responsible to collect all data as required for the power system studies.

B. The firm performing the system studies shall furnish the Contractor with a listing of the required data immediately after award of the contract and the Contractor shall expedite collection of the data to assure completion of the studies prior to final approval of the distribution equipment shop drawings and/or release of the equipment for manufacture.

C. As a minimum, the following input data shall be collected and tabulated:

1. Product data for overcurrent protective devices involved in overcurrent protective device coordination studies. Use equipment names/tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.

2. Minimum and maximum fault contribution, impedance, and X/R ratio of the electric power utility service transformer. Rating, type, and settings of the primary overcurrent protective device that protects the service transformer. Conductor data from the protective device to the service transformer. Contractor shall obtain the required electrical service information directly from the electric power utility. Contactor shall be responsible for all coordination and costs associated with obtaining the utility information.

3. Ampacity and interrupting rating in amperes RMS symmetrical for all switchboards, motor control centers, and panelboards.

4. Circuit breaker and fuse current ratings and types within each switchboard, motor control center, panelboard, variable frequency drive, and equipment control panel.

5. 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.

6. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.

7. Time-current-characteristic curves of protective devices indicated to be coordinated.

8. Distribution system transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.

9. Standby generator kVA, size, voltage, source impedance, and thermaldamage curve.

10. Conductors: conduit material, sizes of conductors, number of conductors per phase, conductor material, insulation, and length.

11. Motor horsepower and code letter designation according to NEMA MG 1. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.

D. Contractor shall obtain required existing equipment data as necessary to satisfy the study requirements.

2.03 SINGLE LINE DIAGRAM

A. A single line diagram of the electrical distribution system shall be prepared in hardcopy and electronic-copy formats.

B. As a minimum, the single line diagram shall show the following:

1. All individual switchboard, switchgear, motor control center, and panelboard equipment buses with voltage, bus ampere ratings, and shortcircuit current ratings.

2. Circuit breaker and fuses with current ratings, amperes interrupting ratings, and types.

3. Motors labeled with horsepower and code letter designation according to NEMA MG 1.

4. Conductor and bus connections between the equipment.

5. Conductor sizes, number of conductors per phase, conductor material and insulation, conductor length, and conduit material.

6. Transformers labeled with size (kVA), voltage, configuration, impedance, and X/R ratio.

7. Generators labeled with size (kVA), voltage, and source impedance.

8. Transfer switches labeled with ampere rating and short-circuit current rating.

2.04 SHORT-CIRCUIT AND PROTECTIVE DEVICE EVALUATION STUDY

A. Use actual conductor impedances if known. If unknown, use typical conductor impedances based on IEEE Standard 141.

B. Transformer design impedances shall be used when test impedances are not available.

C. As a minimum, provide the following:

1. Calculation methods and assumptions

2. Selected base per unit quantities

3. Source impedance data, including electric power utility system and motor fault contribution characteristics

4. Tabulations of input data per Part 2.02 and calculated quantities, including fault impedance, X/R ratios, asymmetry factors, motor contributions, generator contributions (if applicable), and symmetrical and asymmetrical fault currents

5. Single line diagram of the system being evaluated with available fault at each bus, and interrupting rating of devices noted

6. Results, conclusions, and recommendations.

D. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault at each:

1. Electric power utility's supply termination point

2. Incoming switchgear

3. Unit substation primary and secondary terminals

4. Low voltage switchgear and/or switchboard

5. Motor control center

6. Distribution panelboard

7. Branch circuit panelboard

8. Variable frequency drive

9. Standby generator and automatic transfer switch

10. Equipment control panels

11. Other significant locations throughout the system.

E. 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.

F. Equipment, Material, and Protective Device Evaluations:

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

2. Evaluate adequacy of switchgear, switchboard, motor control center, and panelboard bus bars/bracing to withstand short-circuit stresses.

3. Evaluate adequacy of transformer windings to withstand short-circuit stresses.

4. Evaluate conductors and busways for ability to withstand short-circuit heating.

5. Identify any existing circuit protective devices improperly rated for the calculated available fault current.

6. Tabulate all evaluation results.

2.05 PROTECTIVE DEVICE COORDINATION STUDY

A. Perform the protective device study using the approved computer software program. Utilize the results of the short-circuit analysis. Coordination study shall be performed in compliance with IEEE 399.

1. Model 1/2 cycle network (sub-transient network), 1.5 to 4 cycle network (transient), and 30 cycle network (steady-state network). Calculate 1/2 cycle, 1.5 to 4 cycle, and 30 cycle balanced and unbalanced faults for 3phase, L-G, L-L, and L-L-G.

2. Calculate the maximum and minimum 1/2 cycle short-circuit currents.

3. Calculate the maximum and minimum interrupting duty (5 cycles to 2 seconds) short-circuit currents.

4. Calculate the maximum and minimum ground-fault currents.

B. Fault currents and time intervals shall comply with IEEE 241 recommendations.

C. Protect conductors against damage from fault currents according to Insulated Cable Engineers Association (ICEA) Publication P-32-382, ICEA P-45-482, and conductor melting curves 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.

D. Protect transformers against damage from through-fault currents according to ANSI C57.109, IEEE C57.12.00, and IEEE 242.

E. Provide computer software generated time-current characteristic (TCC) plots of all overcurrent protective devices on log-log sheets graphically indicating the coordination for all of the key systems.

F. Perform a sequence of operation that evaluates, verifies, and confirms the operation and selectivity of the protective devices for various types of faults via normalized TCC plots and the single-line diagram. Provide adequate time margins between device characteristics such that selective operation is provided, while providing proper protection.

G. Establish settings and/or ratings of overcurrent protective devices to achieve selective coordination between devices. Graphically illustrate that adequate time separation exists between devices installed in series, including electric power utility's upstream devices. Prepare separate sets of plots for the switching schemes and for emergency periods where the power source is via the emergency standby generator(s).

H. On each TCC plot, include reference voltage, a complete title, and single line diagram with legend identifying the specific portion of the system covered.

I. Identify the device associated with each curve by device designation/tag, manufacturer, type, and function. Terminate the protective device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device will be exposed.

J. The electric power utility's relay, fuse, or protective device shall be plotted with all load protective devices at the same voltage.

K. 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.

L. Fuse curves shall include no damage, melting, and clearing curves as applicable.

M. Circuit breaker curves shall include complete operating bands, terminating with the appropriate available short-circuit current.

N. When the main circuit breaker is provided with an arc-flash reduction maintenance system to reduce the arc fault level, both settings shall be included in the study.

O. Low voltage circuit breakers with adjustable overcurrent protection shall have instantaneous, short delay, and long-time pick-up identified on the plot. Low voltage circuit breakers with ground fault protection shall have ground fault trip settings, ground fault ampere, and time delay settings identified on the plot. Sensor or monitor rating shall be stated for each circuit breaker. All regions of the circuit breaker curve shall be identified.

P. 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 at 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.

Q. The coordination plots shall include significant motor starting characteristics and large motor protective devices.

R. As a minimum, TCC coordination plots shall be provided for the following:

1. Electric power utility's overcurrent protective device

2. Medium voltage equipment overcurrent relays

3. Medium and low voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands

4. Low voltage circuit breakers and fuses, including manufacturer's tolerance bands

5. Transformer full-load and 150, 400, or 600 percent currents, magnetizing inrush current, and ANSI through-fault protection curves

6. Conductor damage curves

7. Ground fault protective devices, as applicable

8. Pertinent motor starting characteristics and motor damage points. For motor control circuits, show motor control center full-load current plus symmetrical and asymmetrical of the largest motor starting current and time to ensure protective devices will not trip during major or group start operation.

9. Pertinent generator short-circuit decrement curve and generator damage point, where applicable. Provide phase and ground coordination of the generator protective devices. Obtain the required input information from the generator manufacturer and include the generator actual impedance value, time constants, and current boost data in the study. Do not use typical values for the generator.

10. Other system load protective devices, including branch circuits and feeder circuit breakers in each motor control center, and main circuit breaker in each branch panelboard.

S. A summary tabulation shall be provided listing the designation/tag, manufacturer, and type for all overcurrent and ground fault protective devices, and all recommended settings of each adjustable band included for each device.

T. Provide an evaluation of the degree of system protection and service continuity possible with the overcurrent devices supplied.

2.06 ARC-FLASH HAZARD STUDY

A. The arc-flash hazard study shall be performed according to the IEEE 1584 guidelines and equations presented in NFPA 70E-2015, Annex D. The analysis shall be performed in conjunction with the Short-Circuit and Protective Device Evaluation Study, and the Protective Device Coordination Study.

B. The flash-protection boundary and the incident energy shall be calculated at all equipment locations in the electrical distribution system where work could be performed on energized parts, including, but not limited to, the following: switchboards, switchgear, motor control centers, panelboards, busway and splitters, and equipment control panels.

C. The Arc-Flash Hazard Study shall include all medium voltage, locations, all 480V locations, and all 240V and/or 208V locations. In addition, the Arc-Flash Hazard Study shall include all DC locations of 50V or greater.

D. Safe working distances shall be based upon the calculated arc-flash boundary considering an incident energy of 1.2 cal/sq cm.

E. When appropriate, the short-circuit calculations and the clearing times of the overcurrent protective devices shall be retrieved from the short-circuit and protective device coordination study model. Ground overcurrent relays should not be taken into consideration when determining the clearing time when performing incident energy calculations.

F. The short-circuit calculations and the corresponding incident energy calculations for multiple system scenarios shall be compared, and the greatest incident energy shall be uniquely reported for each equipment location. Calculations shall be performed to represent the maximum and minimum contributions of fault current magnitude for all normal and emergency operating conditions. The minimum calculation shall assume that the electric power utility contribution is at a minimum and shall assume a minimum motor contribution (all motors off). Conversely, the maximum calculation shall assume a maximum contribution from the electric power utility and shall assume the maximum amount of motors to be operating under full-load conditions. Calculations shall take into consideration the parallel operation of synchronous generators with the electric power utility, where applicable.

G. The 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 3-5 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 3 per unit after 10 cycles).

H. For each equipment location with a separately enclosed main device (where there is adequate separation between the line side terminals of the main protective device and the work location), calculations for incident energy and flashprotection boundary shall include both the line and load side of the main breaker.

I. When performing incident energy calculations on the line side of a main breaker (as required per above), the line side and load side contributions shall be included in the fault calculation.

J. Mis-coordination shall be checked amongst all devices within the branch containing the immediate protective device upstream of the calculation location and the calculation shall utilize the fastest device to compute the incident energy for the corresponding location.

K. Arc-flash calculations shall be based on actual overcurrent protective device clearing time. Maximum clearing time will be capped at 2 seconds based on IEEE 1584, Section B.1.2. Where it is not physically possible to move outside of the flash-protection boundary in less than 2 seconds during an arc-flash event, a maximum clearing time based on the specific location shall be utilized.

L. Determine incident energy and arc-flash PPE requirements for each equipment location. For main circuit breakers with arc-flash reduction maintenance systems, determine two (2) incident energies (one for normal duty and one for maintenance duty).

M. Calculate shock hazard approach boundaries (limited approach boundary and restricted approach boundary) for each equipment location.

N. Provide recommendations to reduce arc-flash hazard energy and exposure.

O. Coordinate with manufacturers/suppliers of the electrical equipment.

2.07 STUDY DATA

The results of all study calculations, analyses, evaluations, and determinations specified in Part 2 herein shall be presented in a detailed, comprehensive report. In addition, data from the computer software analyses shall be included in the study report along with data evaluation and recommendations. Computer analysis data, data evaluation, and recommendations shall include, but not be limited to, the following:

A. Study Input Data

1. Feeder input data including feeder type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic) and conductor material (copper or aluminum).

2. Transformer input data, including winding connections, secondary neutralground connection, primary and secondary voltage ratings, kVA rating, impedance, percent taps and phase shift.

3. Reactor data, including voltage rating, and impedance.

4. Generation contribution data, (synchronous generators and electric power utility), including short-circuit reactance (X"d), rated MVA, rated voltage, three-phase and single-line to ground contribution (for electric power utility sources) and X/R ratio.

5. Motor contribution data (induction motors and synchronous motors), including short-circuit reactance, rated horsepower or kVA, rated voltage, and X/R ratio.

B. Short-Circuit Study

1. Low Voltage Fault Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:

    a. Voltage (600V and less)

    b. Calculated fault current magnitude and angle

    c. Fault point X/R ratio

    d. Equivalent impedance

2. Momentary (First Half-Cycle) Duty Report shall include a section for threephase and unbalanced fault calculations and shall show the following information for each applicable location:

    a. Voltage (greater than 600V)

    b. Calculated symmetrical fault current magnitude and angle

    c. Fault point X/R ratio

    d. Calculated asymmetrical fault currents

        - Based on fault point X/R ratio
        - Based on calculated symmetrical value multiplied by 1.6
        - Based on calculated symmetrical value multiplied by 2.7

    e. Equivalent impedance

3. Interrupting Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:

    a. Voltage (greater than 600V)

    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

g. Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a total basis.

C. Protective Device Coordinating Study:

1. Recommendations for Phase and Ground Relays:

a. Current transformer ratio

b. Current setting

c. Time setting

d. Instantaneous setting

e. Recommendations on improved relaying systems, if applicable.

2. Recommendations for Circuit Breakers:

a. Adjustable pickups and time delays (long time, short time, ground)

b. Adjustable time-current characteristic

c. Adjustable instantaneous pickup

d. Recommendations on improved trip systems, if applicable.

D. Arc-Flash Hazard Study:

2. Incident Energy Calculations:

   a. Arcing fault magnitude

   b. Protective device clearing time

   c. Duration of arc

   d. Incident energy

3. Arc-Flash Protection Boundary Calculations and Recommendations:

   a. Arc-flash boundary

   b. Shock hazard approach boundaries

   c. Personal protective equipment

   d. Recommendations for arc-flash energy reduction.

2.08 IMPLEMENTATION OF STUDY RESULTS

Prior to fabrication, Contractor shall coordinate the study results with the manufacturers and suppliers of electrical equipment to incorporate the recommendations and modifications therein.

2.09 ARC-FLASH AND SHOCK HAZARD LABELS

A. <u>General</u>

1. Labels shall be 4" x 6" thermal transfer type labels of UV resistant high adhesion polyester. Labels shall be machine printed, with no field markings.

2. Labels shall comply with the requirements of the NEC, NPFA 70E, and ANSI Z535.4.

3. All labels shall be based on recommended overcurrent protective device settings and shall be provided after the results of the analyses have been accepted by the District and after any system changes, upgrades or modifications have been incorporated into the system.

4. In general, the arc-flash labels shall be based on the maximum calculated incident energies for the worst case operating scenario. However, where arc-flash reduction maintenance systems are specified, provide two (2) sets of arc-flash labels (one for normal duty and one for maintenance duty).

5. The firm performing the Study shall provide all labels. Equipment elevations drawings showing the location of each label shall be prepared by the firm performing the Study.

6. For outdoor electrical panels with interior enclosures and outer NEMA 3R wrappers, labels shall be provided on both outer and inner doors, as follows:

   a. For incident energy levels less than 40 cal/sq cm, each outer door section shall be provided with a warning label stating "WARNING, ARC-FLASH AND SHOCK HAZARD, APPROPRIATE PPE REQUIRED". The label color scheme shall match the inner arc-flash warning label.

   b. For incident energy levels greater than 40 cal/sq cm, each outer door section shall be provided with a danger label stating "DANGER, ARC-FLASH AND SHOCK HAZARD, NO SAFE PPE EXISTS, ENERGIZED WORK PROHIBITED". The label color scheme shall match the inner arc-flash danger label.

   c. Inner doors shall be provided with arc-flash labels as specified in Parts B and C below.

7. Labels shall be provided for each switchboard, distribution panel, transfer switch (automatic or manual), motor control center, variable frequency drive, distribution panelboard, branch circuit panelboard, busway, enclosed circuit breaker and disconnect switch in a readily visible location in accordance with NEC and OSHA requirements.

8. Where incident energy levels vary across a panel line-up, such as a motor control center, a separate label shall be provided for each section or compartment with a different incident energy level. As a minimum, labels shall be installed every four feet.

B. Warning Labels

1. Warning labels shall be white with an orange stripe and black letters. A sample warning label is presented at the end of this Section.
2. Warning labels shall include the following information:

   a. "WARNING, ARC-FLASH AND SHOCK HAZARDS, APPROPRIATE PPE REQUIRED".

   b. Arc-flash hazard boundary.

   c. Available incident energy (cal/sq cm) and working distance.

   d. Recommended (minimum) PPE from NFPA Table 70E H.3(b)

   e. Maximum available fault current (Isc).

   f. Shock hazard when cover is removed.

   g. Glove class.

   h. Limited approach distance.

   i. Restricted approach distance.

   j. Equipment description and location.

   k. Protective device description.

   l. Operating scenario.

   m. Firm identification (prepared by).

n. Label preparation date.

C. <u>Danger Labels</u>

1. Danger labels shall be white with a red warning stripe and black letters. A sample danger label is presented at the end of this Section.

2. Danger labels shall include the following information:

a. "DANGER, ARC-FLASH AND SHOCK HAZARDS, ENERGIZED WORK PROHIBITED".

b. Arc-flash hazard boundary.

c. Available incident energy (cal/sq cm) and working distance.

d. No safe PPE exists – Do not work on equipment while energized.

e. Available fault current (Isc).

f. Shock hazard when cover is removed.

g. Glove class.

h. Limited approach distance.

i. Restricted approach distance.

j. Equipment description and location.

k. Protective device description.

l. Operating Scenario.

m. Firm identification (prepared by).

n. Label preparation date.

PART 3 - EXECUTION

3.01 PROTECTIVE DEVICE SELECTION AND SETTING

A. Field setting of the protective devices shall be performed as required to place the equipment in final operating condition. The settings shall be in accordance with the approved short-circuit study, protective device evaluation study, and protective device coordination study. Confirmation of protective device selection and performance of device field setting shall be witnessed and verified by the testing consultant performing electrical system testing (reference Specification Section 16010) or by the firm performing the studies.

B. 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 factory defaults settings to the settings recommended in the studies specified herein.

2. Circuit Breakers: Reset all adjustable trip settings from factory default settings to the settings recommended in the studies specified herein.

3. Ground Fault Protection Devices: Reset all adjustable device settings from the factory defaults settings to the settings recommended in the studies specified herein.

4. Fuses: Confirm that fuse types installed on the project are as recommended in the studies specified herein.

C. Necessary field adjustments of devices and minor modifications to equipment to accomplish conformance with the approved studies shall be performed at no additional cost to the District.

D. Contractor shall verify the proper short-circuit duty and amperage rating of all protective devices and bussing. Equipment short-circuit duty and amperage ratings shall be in accordance with the Drawings and equipment specifications, and shall meet or exceed the ratings recommended in the studies specified herein.

3.02 ARC-FLASH AND SOCK HAZARD LABEL INSTALLATION

A. Affix arc-flash and shock hazard labels to all electrical equipment as required by NFPA 70 and NFPA 70E.

B. Install labels in accordance with the approved label location drawings and as specified herein.

3.03 FIELD REPORT

The firm witnessing the confirmation of protective device selection and performance of device field setting shall provide a detailed report showing that selections and settings of protective devices are in compliance with the studies and requirements specified herein. In addition, the report shall include a photographic record of all installed arcflash labels, including locations. The report shall be submitted to the District for acceptance as a submittal document.

ARC-FLASH LABEL EXAMPLES

WARNING

Qualified Persons Only

Arc-Flash and Shock Hazards Appropriate
PPE Required

REVIEW SAFE WORK PRACTICES PRIOR TO WORK

44 in	**Arc-Flash Hazard Boundary**
7.1 cal/cm^2	**Arc-Flash Incident Energy at Work Distance: 18 inches**
5.85 kA	**Maximum Available Fault Current**

Recommended (Minimum) PPE: Arc-rated long sleeve shirt and arc-rated pants, or arc-rated coverall and/or arc-flash suit. Arc-rated arc-flash suit hood, arc-rated gloves, arc-rated jacket, parka, or rainwear. Hard hat, arc-rated hard hat liner, safety glasses, hearing protection, arc-rated gloves, and leather footwear.

480 VAC	**Shock Hazard when Cover is Removed**	**42 in**	**Limited Approach**
00	**Glove Class**	**12 in**	**Restricted Approach**

Equipment/Device Name: MCC-2A **Feed From: MDP-1** **Scenario 2 - Normal Power**	**Study Performed by:** ACME Flash, Inc. **Prepared:** 02/12/16

DANGER

Arc-Flash and Shock Hazards Energized
Work Prohibited

207 in	**Arc-Flash Hazard Boundary**
65 cal/cm^2	**Arc-Flash Incident Energy at Work Distance: 18 inches**
43.8 kA	**Maximum Available Fault Current**

Recommended (Minimum) PPE: No Safe PPE Exists - Do Not Work On Equipment While Energized!

480 VAC	**Shock Hazard when Cover is Removed**	**42 in**	**Limited Approach**
00	**Glove Class**	**12 in**	**Restricted Approach**

Equipment/Device Name: Main CB **Feed From: Service Switchboard** **Scenario 2 - Normal Power**	**Study Performed by:** ACME Flash, Inc. **Prepared:** 02/12/16

END OF SECTION

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