

SECTION 26 05 73 – SHORT-CIRCUIT, COORDINATION AND ARC-FLASH HAZARD STUDIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Computer-based fault-current, overcurrent protective device coordination and arc-flash hazard studies to determine minimum interrupting capacity of circuit protective devices, overcurrent protective device settings for selective tripping, and provide incident energy to which personnel could be exposed during work on or near electrical equipment.
 - a. It is understood that not all overcurrent devices will coordinate; however, an attempt shall be made to coordinate all devices with selectable settings to the best of their ability.

1.2 SUBMITTALS

A. Study Report:

1. Short-circuit, coordination and arc-flash study input data, including completed computer program input data sheets.
2. **Submit short-circuit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect/Engineer for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory**
3. Study and equipment evaluation reports.
4. Revised one-line diagram, reflecting field investigation results and results of coordination and arc-flash study.

1.3 QUALITY ASSURANCE

- A. Studies must be performed using commercially developed and distributed software designed specifically for power system analysis.
- B. Software algorithms must comply with requirements of standards and guides specified in this Section.
- C. Manual calculations are unacceptable.

PART 2 - PRODUCTS

2.1 POWER SYSTEM ANALYSIS SOFTWARE

- A. Comply with IEEE 242, IEEE 399 and IEEE 551.
- B. Analytical features of device coordination study computer software program must have capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

- C. Computer software program must be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program must report device settings and ratings of overcurrent protective devices and must demonstrate selective coordination by computer-generated, time-current coordination plots.
- D. Computer program must be designed to perform coordination studies or have function, component, or add-on module designed to perform coordination studies.
- E. Computer program must be designed to perform arc-flash analysis or have function, component, or add-on module designed to perform arc-flash analysis.
- F. Computer program must be developed under supervision of licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

2.2 SHORT-CIRCUIT STUDY REPORT CONTENTS

- A. Executive summary of study findings.
- B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.
- C. One-line diagram of modeled power system, showing the following:
 - 1. Protective device designations and ampere ratings.
 - 2. Conductor types, sizes, and lengths.
 - 3. Transformer kVA and voltage ratings.
 - 4. Motor and generator designations and kVA ratings.
 - 5. Switchgear, switchboard, motor-control center, and panelboard designations and ratings.
 - 6. Derating factors and environmental conditions.
 - 7. Any revisions to electrical equipment required by study.
- D. Comments and recommendations for system improvements or revisions in written document, separate from one-line diagram.
- E. Protective Device Evaluation:
 - 1. Evaluate equipment and protective devices and compare to available short-circuit currents. Verify that equipment withstand ratings exceed available short-circuit current at equipment installation locations.
 - 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. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in standards to 1/2-cycle symmetrical fault current.
 - 5. 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.
- F. Short-Circuit Study Input Data:
 - 1. One-line diagram of system being studied.
 - 2. Power sources available.

3. Manufacturer, model, and interrupting rating of protective devices.
4. Conductors.
5. Transformer data.

G. Short-Circuit Study Output Reports:

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.
 - 2) Based on calculated symmetrical value multiplied by 1.6.
 - 3) Based on calculated symmetrical value multiplied by 2.7.
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. No AC Decrement (NACD) ratio.
 - e. Equivalent impedance.
 - f. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on symmetrical basis.
 - g. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on total basis.

2.3 COORDINATION STUDY REPORT CONTENTS

- A. Executive summary of study findings.
- B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.
- C. One-line diagram of modeled power system, showing the following:
 1. Protective device designations and ampere ratings.
 2. Conductor types, sizes, and lengths.
 3. Transformer kVA and voltage ratings.
 4. Motor and generator designations and kVA ratings.
 5. Switchgear, switchboard, motor-control center, and panelboard designations.
 6. Revisions to electrical equipment required by study.
 7. Study Input Data.

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D. Protective Device Coordination Study:

1. Report recommended settings of protective devices, ready to be applied in field. Use manufacturer's data sheets for recording 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, and 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.

E. 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 switching schemes and for emergency periods where power source is local generation. Show the following information:

1. Device tag and title, one-line diagram with legend identifying portion of system covered.
2. Terminate device characteristic curves at point reflecting maximum symmetrical or asymmetrical fault current to which device is exposed.
3. Identify 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 (when applicable).
 - c. Medium- and low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands (when applicable).
 - 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 (when applicable).
 - 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. Largest feeder circuit breaker in each motor-control center and panelboard.
5. Maintain selectivity for tripping currents caused by overloads.
6. Provide adequate time margins between device characteristics such that selective operation is achieved.
7. Comments and recommendations for system improvements.

2.4 ARC-FLASH STUDY REPORT CONTENT

- A. Executive summary of study findings.
- B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.
- C. One-line diagram, showing the following:
 - 1. Protective device designations and ampere ratings.
 - 2. Conductor types, sizes, and lengths.
 - 3. Transformer kVA and voltage ratings, including derating factors and environmental conditions (when applicable).
 - 4. Motor and generator designations and kVA ratings.
 - 5. Switchgear, switchboard, motor-control center, panelboard designations, and ratings.
- D. Study Input Data.
- E. Arc-Flash Study Output Reports:
 - 1. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each equipment location included in report:
 - a. Voltage.
 - b. Calculated symmetrical fault-current magnitude and angle.
 - c. Fault-point X/R ratio.
 - d. No AC Decrement (NACD) ratio.
 - e. Equivalent impedance.
 - f. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on symmetrical basis.
 - g. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on total basis.
- F. Incident Energy and Flash Protection Boundary Calculations:
 - 1. Arcing fault magnitude.
 - 2. Protective device clearing time.
 - 3. Duration of arc.
 - 4. Arc-flash boundary.
 - 5. Restricted approach boundary.
 - 6. Limited approach boundary.
 - 7. Working distance.
 - 8. Incident energy.
 - 9. Hazard risk category.
 - 10. Recommendations for arc-flash energy reduction.
- G. Fault study input data, case descriptions, and fault-current calculations including definition of terms and guide for interpretation of computer printout.

2.5 ARC-FLASH WARNING LABELS

- A. Produce 3.5 by 5-inch self-adhesive equipment label for each work location included in analysis.

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- B. Label must have orange header with wording, "WARNING, ARC-FLASH HAZARD," and must include the following information taken directly from arc-flash hazard analysis:
 - 1. Location designation.
 - 2. Nominal voltage.
 - 3. Protection boundaries.
 - a. Arc-flash boundary.
 - b. Restricted approach boundary.
 - c. Limited approach boundary.
 - 4. Arc flash PPE category.
 - 5. Required minimum arc rating of PPE in Cal/cm squared.
 - 6. Available incident energy.
 - 7. Working distance.
 - 8. Engineering report number, revision number, and issue date.
- C. Labels must be machine printed, with no field-applied markings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance of the Work. Devices to be coordinated are indicated on Drawings.
 - 1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to coordination study may not be used in study.
- B. Examine Project overcurrent protective device submittals. Proceed with arc-flash study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to arc-flash study may not be used in study.

3.2 POWER SYSTEM DATA

- A. It shall be the responsibility of the Contractor to obtain additional data as required in order to complete the studies as outlined in this specification, including, but not limited to utility information.
- B. For equipment that is existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers in accordance with NFPA 70E.

3.3 SHORT-CIRCUIT STUDY

- A. Perform study following general study procedures contained in IEEE 399.
- B. Calculate short-circuit currents according to IEEE 551.
- C. Base study on device characteristics supplied by device manufacturer.

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- D. Provide study throughout entire distribution, extending to, and including major mechanical equipment, including, but not limited to Chiller(s), cooling tower(s), modular and packaged rooftop and interior air handling units as outlined below.
- E. Begin short-circuit current analysis at service, extending down to system overcurrent protective devices as follows:
 - 1. To normal system low-voltage load buses where fault current is 5 kA or less.
- F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study cases of system-switching configurations and alternate operations that could result in maximum fault conditions.
- G. Include ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and apply to low- and medium-voltage, three-phase ac systems. Also account for fault-current dc decrement to address asymmetrical requirements of interrupting equipment.
- H. Calculate short-circuit momentary and interrupting duties for three-phase bolted fault and single line-to-ground fault at each equipment indicated on one-line diagram.
 - 1. For grounded systems, provide bolted line-to-ground fault-current study for areas as defined for three-phase bolted fault short-circuit study.
- I. Include in report identification of protective device applied outside its capacity.

3.4 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. Base study on device characteristics supplied by device manufacturer.
- D. The coordination study shall be completed with sufficient information in order to provide appropriate data to adjust breaker settings, and size fuses where indicated to be sized.
- E. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

3.5 FIELD ADJUSTING

- A. Adjust relay and protective device settings according to recommended settings provided by coordination study. Field adjustments must be completed by engineering service division of equipment manufacturer.
- B. Make minor modifications to equipment as required to accomplish compliance with protective device coordination studies.
- C. Testing and adjusting must be by qualified electrical testing and inspecting agency.
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for adjustable overcurrent protective devices.

3.6 ARC-FLASH HAZARD ANALYSIS

- A. Comply with NFPA 70E and its Annex D for hazard analysis study.
- B. Preparatory Studies: Perform Protective Device Coordination study prior to starting Arc-Flash Hazard Analysis. Complete a short-circuit study as required in order to complete the arc-flash hazard analysis study.
- C. Calculate maximum and minimum contributions of fault-current size.
 - 1. Maximum calculation must assume maximum contribution from utility and must assume motors to be operating under full-load conditions.
 - 2. Calculate arc-flash energy at 85 percent of maximum short-circuit current in accordance with IEEE 1584 recommendations.
 - 3. Calculate arc-flash energy at 38 percent of maximum short-circuit current in accordance with NFPA 70E recommendations.
- D. Calculate arc-flash protection boundary and incident energy at locations in electrical distribution system where personnel could perform work on energized parts.
- E. Include medium- and low-voltage equipment locations, except equipment fed from transformers smaller than 75 kVA.
- F. Calculate limited, restricted, and prohibited approach boundaries for each location.
- G. Incident energy calculations must consider accumulation of energy over time when performing arc-flash calculations on buses with multiple sources. Iterative calculations must take into account changing current contributions, as sources are interrupted or decremented with time. Fault contribution from motors and generators must be decremented as follows:
 - 1. Fault contribution from induction motors must not be considered beyond three to five cycles.
 - 2. Fault contribution from synchronous motors and generators must be decayed to match actual decrement of each as closely as possible (for example, contributions from permanent magnet generators will typically decay from 10 p.u. to 3 p.u. after 10 cycles).
- H. Arc-flash energy must generally be reported for maximum of line or load side of circuit breaker. However, arc-flash computation must be performed and reported for both line and load side of circuit breaker as follows:
 - 1. When circuit breaker is in separate enclosure.
 - 2. When line terminals of circuit breaker are separate from 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.

3.7 ARC-FLASH LABELING

- A. Apply one arc-flash label on front cover of each section of equipment for each equipment included in study. Base arc-flash label data on highest values calculated at each location.
- B. Each piece of equipment listed below not fed by single transformer smaller than 75 kVA must have arc-flash label applied to it:
 - 1. Medium-voltage switchgear (when on project).

2. Medium-voltage switches (when on project).
 3. Medium voltage transformers (when on project).
 4. Switchboards.
 5. Panelboards.
 6. Motor-control centers (when on project).
 7. Low voltage transformers.
 8. Disconnect switches.
- C. Note on record drawings location of equipment where personnel could be exposed to arc-flash hazard during their work.
1. Indicate arc-flash energy.
 2. Indicate protection level required.

3.8 APPLICATION OF WARNING LABELS

- A. Install arc-flash warning labels under direct supervision and control of qualified electrical professional engineer.

END OF SECTION 26 05 73