

POWER SYSTEMS STUDY SPECIFICATION

Load Flow Study

Fault Study

Protective Device Coordination

Arc Flash Analysis

THIS STUDY SPECIFICATION DOCUMENT CONTAINS METHODS AND PROCEDURES FOR CONDUCTING LOAD FLOW STUDY, FAULT STUDY, PROTECTIVE DEVICE COORDINATION, AND ARC-FLASH HAZARD ASSESSMENT. PROFESSIONAL JUDGMENT MUST BE USED IN CONJUNCTION WITH THE APPLICABLE STANDARDS AND GUIDELINES. ETAP DISCLAIMS ALL WARRANTIES, RESPONSIBILITIES, AND LIABILITIES, EITHER EXPRESS OR IMPLIED, RESULTING FROM THE USE AND INTERPRETATION OF THIS STUDY SPECIFICATION DOCUMENT.

Legend:

1. User-definable information highlighted in **Yellow**
2. Optional information highlighted in **Green**

POWER SYSTEMS STUDY SPECIFICATION

Load Flow Study, Fault Study, Protective Device Coordination, Arc Flash Analysis

PART 1 - INTRODUCTION

Enter Company & power system information here

PART 2 - STUDY OBJECTIVE

Company desires to conduct an arc flash hazard study to identify potential hazards supplement/enhance their existing electrical safety program; provide additional safety measures for their employees. After the study, Company will review the recommendations & proceed with implement as appropriate.

PART 3 - SCOPE OF WORK

Company is soliciting proposals from the qualified consultant to perform Power Systems Analysis Study. The successful consultant will assist Company with the following:

- Site visit
 - Review of the safety procedure, and facility conditions to determine what steps need to be taken to perform power system study
 - Collection of additional data
 - Verification of equipment nameplate ratings
- Verification of the ETAP model & updated the as built study as required.
- Verify the protection relay setting & coordination study.
- Final recommendation of the Arc Flash Study to be implemented

NOTE: It is the consultant's responsibility to become familiar with all regulation(s) applicable to the work required in this Request for Proposal.

The analysis shall consist of the following:

- Data Collection
- System Modeling
- Model Verification & Validation
- Fault & Device Duty Evaluation study
- Protective Device Coordination study
- Arc Flash Hazard Assessment
- Project Deliverables including detailed report of findings & recommendations

PART 4 - INPUT DATA

- A. Overall key single line diagram (Attachment #)
- B. List of switchgears (Attachment #)
- C. Switchgear single line diagrams (Attachment #)
- D. Previous power system study (Attachment #)
- E. Load schedules (Attachment #)
- F. Protective relay setting sheets (Attachment #)

PART 5 - GENERAL

5.1 Summary

- A. The following are general requirements for a Fault, Protective Device Coordination and Arc Flash study. The Electrical Consultant/Contractor shall perform a study for the purposes of estimating worst case available short circuit current values and Arc Flash incident energy. The final study will be generated based on the final electrical equipment submittals and the final pulled conductor lengths for all feeders.
- B. Based on the findings of the final report, the electrical consultant/contractor shall adjust all required protective device settings based on the results of the protective device coordination and/or Arc Flash study.
- C. The electrical consultant/contractor shall also install Arc Flash PPE (Personal Protective Equipment) labels on all switchboards and panelboards provided as part of the Arc Flash Study.

5.2 Submittals

- A. The following submittals shall be made after the approval process for system protective devices has been completed. Submittals may be in digital form.
 - 1. Complete input data report, including computed generated protected device settings report
 - 2. Load Flow Study
 - 3. Load Flow, Short Circuit & Arc Flash analyzer reports in MS Excel format. Short Circuit & Arc Flash result analyzer reports shall indicate worst case scenario conditions and associated results.
 - 4. Short Circuit Study, Device Duty & Equipment Evaluation Reports
 - 5. Coordination Study Report including computer generated Time-current Characteristic Curves (TCC)
 - 6. Arc Flash Study Report and Personal Protective Equipment Labels
 - 7. Electronic copy of computer software (project) model

5.3 Quality Assurance

- A. Study shall use a robust electrical power system design and analysis software which complies with requirements of standards and guides specified in this Section. Manual calculations are not acceptable.

- B. Software should be developed under established quality assurance program. Software QA program shall comply with ISO 9000 with accredited certification agency such as UL. Software calculations and engineering library compliance with U.S. Title 10 CFR #50, Appendix B and related Software Standards is preferred.

5.4 Engineering Qualifications

- A. A consultant/contractor experienced in the application of computer software used for studies, having performed successful studies of similar magnitude on electrical systems using similar devices.
- B. Professional engineer, licensed in the state where Project is located, shall be responsible for supervision and approval of the study. All elements of the study shall be performed under the direct supervision and control of the professional engineer.
- C. The Registered Professional Electrical Engineer shall be a full-time employee of the equipment manufacturer or an approved engineering firm.
- D. The Registered Professional Electrical Engineer shall have a **minimum of five (5) years** of experience in performing power system studies.
- E. The equipment manufacturer or approved engineering firm shall demonstrate experience with Arc Flash Hazard Analysis by submitting names of **at least ten** actual arc flash hazard analysis it has performed in the past year.

5.5 References

- A. Institute of Electrical and Electronics Engineers (IEEE):
- IEEE 242 for short circuit currents and coordination time intervals
 - IEEE 399 for general study procedures
 - IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems
 - IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings
 - IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.
 - IEEE 1584 – Guide for Performing Arc Flash Hazard Calculations
- B. American National Standard Institute (ANSI):

- ANSI C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- ANSI C37.13 – Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures
- ANSI C37.010 – Standard Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI C37.41 – Standard Design Tests for High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories

C. National Fire and Protection Association (NFPA):

- NFPA 70 – National Electrical Code (Latest Edition)
- NFPA 70E – Standard for Electrical Safety in the Workplace

PART 6 - Software Program

6.1 Power System Analysis Software Program (Software)

- A. Software shall have a robust Quality Assurance Program in place and subject to QA audits assessments.
- B. Studies shall be performed using the latest version of approved software:
- ETAP (Developed by ETAP / Operation Technology, Inc.)
 - Approved equal
- C. Software Program Requirements
- Software shall comply with IEEE 399, IEEE 141, IEEE 242, IEEE 1015, IEEE 1584.

PART 7 - EXECUTION

7.1 Power System Data

A. Gather and tabulate the following input data to support the power systems study:

1. Product Data for 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. Maximum fault contribution or Impedance of utility service entrance
3. Electrical Distribution System Diagram: In hard-copy and electronic-copy formats, showing the following:
 - a. Circuit-breaker and fuse-current ratings and types
 - b. Generator kilovolt amperes, size, voltage, and source impedance
 - c. Cables: Indicate conduit material, sizes of conductors, conductor material, insulation, and length
 - d. Motor horsepower and code letter designation according to NEMA MG 1
4. 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 interrupting rating in amperes rms symmetrical
- B. Software shall have the ability to utilize typical data such as %Z, X/R ratios for transformers, etc. in case these values cannot be ascertained from existing documentation and/or field data collection.
- C. Various system operating configurations of the system including status of switching devices and load status (continuous, intermittent, spare), etc. shall be modeled as part of the project database using a configuration management tool.
- D. Study related scenarios including data revisions, engineering properties, study solution parameters & network topology shall be setup. In the event of system changes, these scenarios may be utilized by Company at a later date to re-run the studies.

7.2 Load Flow Study

- A. Load flow study shall be performed to evaluate the system's capability to adequately supply the connected load and prevent overloading of equipment.
- B. Compare equipment (transformers, cables, breakers, fuses) operating values against manufacturer's specified maximum capability ratings whenever available.
- C. Provide a computer generated Alert View list/report which lists all equipment that is critically overloaded.
- D. Load Flow study should consider various operating conditions (scenarios) such as; maximum loading, minimum loading and normal loading.
- E. Provide a computer generated load flow analysis report that provides a summarized comparison of power flow results between the different scenarios being evaluated.

7.3 Fault Study

- A. Software shall have the ability to generate a single Fault Current report that includes the Device Duty Evaluation as per ANSI/IEEE C37 standards.

- B. Calculate the maximum available short circuit current in amperes rms symmetrical at circuit-breaker positions of the electrical power distribution system. The calculation shall be for a current immediately after initiation and for a three-phase bolted short circuit at each of the following:
- Switchgear, switchboard , busways, bus duct
 - Distribution panelboard
 - Branch circuit panelboard
- C. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Include studies of system-switching configurations and alternate operations that could result in maximum fault conditions
- D. Calculate momentary and interrupting duties on the basis of maximum available fault current at each location:
1. Electric utility's supply termination point
 2. Incoming 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
 8. Other significant locations throughout the system
- E. Calculations to verify interrupting ratings of overcurrent protective devices shall comply with IEEE 241 and IEEE 242
- F. Fault Study report shall include:
1. Show calculated X/R ratios and equipment interrupting rating (1/2-cycle) fault currents on electrical distribution system diagram.
 2. Calculation methods and assumptions including any adjustments used when considering resistance and impedance tolerances.
 3. One-line diagram of the system being evaluated with available fault at each bus
 4. Typical calculations

5. Comparison of Short Circuit results from different scenarios in a single display
6. Results, conclusions, and recommendations

G. Device Duty Equipment Evaluation Report:

1. For 600 V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.
2. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in the standards to 1/2-cycle symmetrical fault current.
3. 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.
4. Software shall have the ability to generate a single Fault Current report that includes the Device Duty Evaluation as per ANSI/IEEE C37 standards

H. Software shall utilize data revisions to track system data changes such as “As Found” and “Recommended” settings.

7.4 Protective Device Coordination Study

- A. Perform coordination study using approved computer software program. Prepare a written report using results of fault-current study. Comply with IEEE 399.
1. Calculate the maximum and minimum 1/2-cycle short circuit currents
 2. Calculate the maximum and minimum interrupting duty (5 cycles to 2 seconds) short circuit currents
 3. Calculate the maximum and minimum ground fault currents
- B. Software shall be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.
- C. Software shall be able to perform a Sequence of Operation that evaluates, verifies, and confirms the operation and selectivity of the protective devices for various types of faults directly from the one-line diagram and via normalized Time Current Characteristic Curve views.
- D. Generate a report that highlights detected violations and concerns of equipment protection and device coordination:

1. List possible corrections and adjustments of protective device settings
 2. Provide violation descriptions with each detection provided
- E. Comply with IEEE 241 recommendations for fault currents and time intervals.
- F. Conductor Protection: Protect cables against damage from fault currents according to ICEA 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.
- G. Transformer Protection: Protect transformers against damage from through fault currents according to ANSI C57.109, IEEE C57.12.00, IEEE 242
- H. Low-Voltage Circuit Breakers: IEEE 1015 and IEEE C37.20.1
- I. Coordination Study Report: Prepare a written report indicating the following results of coordination study:
1. Computer generated Overcurrent Protective Devices report must include:
 - a. Device tag
 - b. Current transformer ratios; and tap, time-dial, and instantaneous-pickup values
 - c. Circuit breaker sensor rating; and long-time, short-time, and instantaneous settings
 - d. Fuse current rating and type
 - e. Ground fault relay-pickup and time-delay settings
 2. Coordination Curves: Prepared to 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:
 - a. Device tag
 - b. Voltage and current ratio for curves
 - c. Three-phase and single-phase damage points for each transformer

- d. Melting and clearing curves for fuses
 - e. Cable damage curves
 - f. Transformer inrush points
 - g. Maximum fault-current cutoff point
- J. Provide a computer generated data sheet report for setting of overcurrent protective devices
- K. Software shall utilize data revisions to track system data changes such as “As Found” and “Recommended” settings.

7.5 Arc Flash Study

- A. Perform Arc Flash analysis according to the IEEE 1584 guidelines and equations presented in NFPA 70E-2015, Annex D. Analysis shall be performed in conjunction with Short Circuit analysis and Protective Device Time-Current Coordination analysis.
- B. Incident Energy and Flash protection boundary shall be calculated at all location where energized work could be performed such as switchboards, switchgear, motor control centers, panel boards, busway and tie breakers.
- C. Working distances shall be based on IEEE 1584. The calculated arc flash protection boundary shall be determined using those working distances.
- D. Calculations must be performed to represent the maximum and minimum contributions of fault current magnitude for normal and emergency operating conditions. The minimum calculation shall assume that the utility contribution is at a minimum and shall assume a minimum motor load. Conversely, the maximum calculation shall assume a maximum contribution from the utility and shall assume motors to be operating under full-load conditions.
- E. Multiple system configurations and operating conditions shall be considered and greatest incident energy must be selected for each equipment location.
- 1. Provide a tabular view report of all configurations and operating conditions used
 - 2. Provide calculation methods and assumptions including any adjustments used when considering resistance and impedance tolerances.
- F. When applicable, Utility Minimum and Maximum contributions should be considered. Calculations shall also take into consideration the parallel operation of local generators with utility source as well as any stand-by generators.

- G. Include scenarios when the main source protective devices are or are not adequately isolated from the bus and may fail to operate or be capable of de-energizing the arc fault before it escalates into a line-side arc fault.
- H. Arc flash computation shall include both line and load side of main breaker calculations, where necessary.
- I. The Arc flash analysis shall include all MV, 575 volt, & 480 volt locations and significant locations in 240 volt and 208 volt systems fed from transformers equal to or greater than 125 kVA.
- J. Arc Flash Study report:
 - 1. Arc Flash reports shall compare results from the various arc flash hazard assessments and be capable of filtering the “worst case” Arc Flash analysis results coming from different scenarios in a single table report.
 - 2. Provide a report in a tabulated format that displays the sequence of operation of protective devices during an arc fault.
 - 3. Recommendations for arc flash energy reduction including the use of arc reduction maintenance switches, current limiting fuses, replacement of overcurrent protective devices and/or trip units, or replacement of equipment with arc resistant or preventative designs.
- K. Software shall utilize data revisions to track system data changes such as “As Found” and “Recommended” settings.
- L. Arc Flash Warning Labels:
 - 1. Consultant shall provide a 3.5 in. x 5 in. thermal transfer type label of high adhesion polyester for each work location analyzed.
 - 2. All labels will be based on recommended overcurrent device settings and will be provided after the results of the analysis have been presented to the Company and after any system changes, upgrades or modifications have been incorporated in the system.
 - 3. The label shall include the following information, at a minimum:
 - a. Location
 - b. Nominal voltage
 - c. Flash protection boundary
 - d. Hazard risk category
 - e. Incident energy

- f. Working distance
 - g. Engineering study number, revision number and issue date
4. Arc Flash warning label sample is shown below:



Arc Flash and Shock Hazard Present

Appropriate PPE Required

Arc Flash Boundary	5.7 ft	Minimum PPE Requirements FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)
Incident Energy in cal/cm ²	5.7	
Working Distance	24 in	
Shock Hazard Exposure	480 VAC	
Insulating Gloves Class	00	
Shock Hazard when covers removed		
Limited Approach Boundary	3.5 ft	
Restricted Approach Boundary	1.0 ft	

5. Equipment Location Main_PNL 06-18-2015
- 6. Labels shall be machine printed, with no field markings.
 - 7. Arc flash labels shall be provided in the following manner and all labels shall be based on recommended overcurrent device settings.
 - a. For each 600, 480 and applicable 208 volt panelboard, one arc flash label shall be provided
 - b. For each motor control center, one arc flash label shall be provided
 - c. For each low voltage switchboard, one arc flash label shall be provided
 - d. For each switchgear, one flash label shall be provided.
 - e. For medium voltage switches one arc flash label shall be provided
 - 8. Labels shall be installed by the engineering services division of the Company under the Startup and Acceptance Testing contract portion.

7.6 Training

A. Project Training

1. Training will be on-site and for duration of three (3) days for two (2) electrical engineers from Client's staff. The training will include:
 - a. Basic use of ETAP package as outlined in the software package tutorials and user's guide manuals.
 - b. Explanation of procedures that were used in developing the topology and the set-up of this project.
 - c. Steps that would be involved in modifying and/or expanding system topology for the future revisions and/or upgrades of the equipment and the plant electrical distribution configuration.
 - d. The use of the device library and the procedures in creating new devices or modifying existing devices.

B. Arc Flash Training

1. Consultant shall train the owner's qualified electrical personnel of the potential arc flash hazards associated with working on energized equipment (minimum of 4 hours).
2. The training shall be certified for continuing education units (CEUs) by the International Association for Continuing Education Training (IACET) or equivalent.