This master should be used by designers working on Port of Portland construction projects and by designers working for PDX tenants (“Tenants”). Usage notes highlight a few specific editing choices, however the entire section should be evaluated and edited to fit specific project needs.

Use this section only if the Contractor will provide arc flash analysis and labels. Coordinate with Section 260553, Identification for Electrical Systems.

SECTION 260573 - ELECTRICAL SYSTEMS ANALYSIS

1. GENERAL
	* + 1. DESCRIPTION
				1. This section describes the electrical systems analysis that shall be performed by the Contractor. The analysis shall include all portions of the electrical distribution system from the normal power sources, including adjustable trip circuit breakers, main breakers, and the largest feeder breakers in branch circuit panelboards. Normal system connections and those that result in maximum fault conditions shall be adequately covered in the analysis.
				2. Show coordination from the nearest upstream device not installed by the Contractor, to the downstream overcurrent device not installed by the Contractor, if applicable. Ground fault time current curves shall include 20 amp branch breakers. Emergency and standby systems shall meet code requirements for selective coordination.

Provide substation/panel information in the blanks below. Also, select PGE or PacifiCorp and delete the brackets.

* + - * 1. The analysis shall be limited to all loads fed from \_\_\_\_\_\_\_\_\_\_\_\_\_, which is supplied from [PGE] [PacifiCorp] feeder \_\_\_\_\_\_\_\_\_\_\_\_\_. The Contractor shall obtain from the utility the minimum, normal, and maximum operating voltage levels for short circuit, three-phase short circuit MVa and X/R ratio, as well as line-to-ground short circuit MVa and X/R ratio at the point of connection as shown on the drawings.
				2. The analysis shall consist of the following:

Short circuit study.

Protective device coordination study.

Electronic data files used for the short circuit, coordination, and arc flash studies.

* + - * 1. Device settings shall be set to achieve arc flash incident energy of 8 cal/cm2 or less. Arc flash incident energy above 8 cal/cm2 shall be submitted to the Port for review.
			1. RELATED WORK SPECIFIED ELSEWHERE
				1. Section 260553, Identification for Electrical Systems
			2. REFERENCES
				1. ANSI: American National Standards Institute.

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

ANSI C37.13: Low-Voltage AC Power Circuit Breakers Used in Enclosures

ANSI C57.12.00: Liquid-Immersed Distribution Power and Regulating Transformers

* + - * 1. IEEE: Institution of Electrical and Electronics Engineers.

IEEE 141: Recommended Practice for Electric Power Distribution for Industrial Plants

IEEE 242: Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

IEEE 399: Recommended Practice for Industrial and Commercial Power Systems Analysis

* + - * 1. NFPA: National Fire Protection Association.

NFPA 70E: Standard for Electrical Safety in the Workplace

NEC: National Electrical Code

* + - 1. SUBMITTALS
				1. Submit the following:

A preliminary electrical systems analysis including:

A complete preliminary short circuit study and arc flash analysis. Submit prior to submittal of the distribution equipment shop drawings. If formal completion of the short circuit study will cause a delay in ordering the equipment, approval from the Port may be obtained for submittal of a draft study containing sufficient data to ensure that the selection of device ratings and characteristics will be satisfactory.

Provide number of days in blank below.

A complete protective device coordination study. Submit no later than \_\_ days after approval of the preliminary short circuit study.

Distribution equipment shop drawings clearly indicating that the ratings of proposed equipment meet or exceed the ratings recommended in the studies submitted above.

An updated and complete electrical systems analysis(ESA) utilizing characteristics of as-installed equipment and materials. Submit two copies prior to substantial completion of the work. System analysis shall consist of:

Short circuit study.

Protective device coordination study (PDC).

Arc flash hazard analysis.

Final Report:

Submit electronic copy of the ESA file.

* + - 1. QUALITY ASSURANCE
				1. Prepare short circuit protective device coordination, and arc flash hazard analysis studies in accordance with the latest standards of ANSI C37.010 and C37.13; and IEEE 141, 242, and 399; NFPA 70E; and NEC.
				2. The electrical systems analysis shall be performed by EAS, EDAN, IDC, R&W Engineering, Cundiff Engineering, Power Engineers, The Harris Group, Vertiv, Electrical System Analysis, Inc. (ESANW), or pre-bid approved equal. Provide all pertinent information required to complete the analysis.

The analysis shall be performed, stamped, and signed by a registered professional engineer.

* + - * 1. Prepare the analysis with the latest version of EasyPower power system modeling software, or pre-bid approved equal.
			1. GENERAL ANALYSIS REQUIREMENTS
				1. Equipment and component titles used in the modeling software shall be identical to the equipment and component titles shown on the drawings.
				2. The short circuit study shall define short circuit requirements.

Perform complete fault calculation for each proposed and ultimate source and load combination.

Source combination shall include present and future power company supply circuits.

Coordinate as necessary with the electric utility for determining the available fault current.

* + - * 1. The coordination study shall provide settings for all electrical overcurrent devices to ensure protection of equipment and personnel. Settings shall meet coordination requirements as defined by the NEC.

Prepare device coordination time-current curves (TCC’s) for low and medium voltage distribution systems. The study shall present an organized time‑current analysis of each protective device in the series from the individual device back to the source. The study shall reflect the operation of each device during normal and contingency operating conditions.

For low voltage systems, develop TCC’s for both phase and ground protective devices. Develop one phase and one ground TCC for each unit substation. The TCC shall show the largest feeder from the secondary switchgear down to the MCC or panel load, and the unit service feeder from the medium voltage switchgear. Ground fault calculations shall be made down to a standard 20A/1P circuit breaker. For secondary switchboards serving large loads or a wide variety of loads that may affect upstream coordination, additional TCC’s may be required.

For medium voltage systems, develop TCC’s for both phase and ground protective devices, and include all feeders and ground circuits.

Prepare coordination curves to determine the required settings of protective devices to ensure selective coordination and full utilization of the equipment. The curves shall graphically illustrate on log paper that adequate time separation exists between series devices. The specific time‑current characteristics of each protective device shall be plotted in such a manner that all upstream devices will be clearly depicted on one sheet.

The complete coordination study shall include a system one-line diagram and protective device coordination curves.

The following specific information shall also be shown on the coordination curves:

Device identification shall be displayed from top to bottom, from upstream device to downstream device so that the curve descriptions are in order with the coordination requirement. Coordination curves shall show protective device above and below the new scope of work to demonstrate new system coordination.

Voltage and current ratio for curves.

Three‑phase and single line-to-ground short circuit ANSI damage points for each transformer.

Transformer inrush points.

Minimum melting and clearing curves for fuses, and if available, the no-damage curve.

Cable damage curves.

Motor-starting locked rotor curves, and if available, the motor-locked rotor damage point.

Maximum short circuit cut‑off point.

Clearly marked short circuit current levels through each protective device/branch. These should be based on the appropriate current through the device, i.e., momentary, interrupting, or 30-cycle current.

Protective device one-line diagram clearly showing all protective devices on the time current curve, labels for each device, open breakers, faulted buses, and the short circuit current flowing in each branch.

Develop a table to summarize the settings selected for the protective devices. The table shall include the following:

Device identification.

For low voltage breakers, the circuit breaker manufacturer, type, and style, sensor rating, long‑time, short‑time, instantaneous settings, and time bands. For breakers with ground fault capability, include the pickup and time delay.

Fuse manufacturer, type, style, and rating.

Protective relay manufacturer, type, style, function (51, 50, 67, etc.), pickup, current multiplier, time dial, and delay. For multi-function units, list all devices being used. Include the CT and/or PT ratios for each function.

* + - * 1. Verify:

Equipment ratings.

Equipment is applied within its rating.

Adequacy of equipment to transfer real and reactive power flows and maintain proper system voltages.

Proper transformer taps to maintain system voltages.

Limit hazard risk to 8 cal/cm2 or less, unless otherwise approved by the Port.

* + - 1. SHORT CIRCUIT STUDY
				1. General:

Use cable impedances based on copper conductors.

Use bus impedances based on copper bus bars.

Use cable and bus resistances calculated at 25ºC.

Use medium voltage cable reactance based on actual cable information available.

Use 600-volt cable reactance based on use of typical dimensions of XHHW conductors.

Use actual transformer impedances if known, or use 92.5 percent of the specified impedance based on tolerances as specified by ANSI.

* + - * 1. Provide:

Calculation methods and assumptions.

Selected base per unit quantities.

One-line diagrams.

Source impedance data, including electric utility system characteristics.

Typical calculation.

Tabulations of calculated quantities.

Results, conclusions, and recommendations.

Where devices are not adequately rated for fault current, the noncompliant system shall be checked for “series rated devices.” Series rated devices shall not be used by default and shall be submitted to the Port for approval.

* + - * 1. Calculate short circuit interrupting and momentary (when applicable) duties for an assumed three-phase bolted fault at each:

Electric utility’s supply termination point.

Transformer primary and secondary terminal.

15kV and 480V switchgear.

15kV padmount switch.

Branch circuit panelboard.

Significant location throughout the system.

* + - * 1. Set breakers to allow for full utilization of connected equipment.
				2. Provide bolted line-to-ground fault current study for medium voltage switchgear and switches.
				3. Verify:

Equipment and protective devices are applied within their ratings.

Adequacy of switchgear, padmount switches, and bus bars to withstand short circuit stresses.

Adequacy of transformer windings to withstand short circuit stresses.

Cable sizes for ability to withstand short circuit heating, besides normal load currents.

* + - 1. PROTECTIVE DEVICE COORDINATION STUDY
				1. Obtain utility settings for remote utility substation feeder relays and fuses as required.
				2. Provide coordination between each panelboard’s main circuit breaker and each of its branch circuit breakers.
				3. Provide proposed protective device coordination time-current curves for the revised distribution systems, graphically displayed on log-log curve sheets.
				4. Each curve sheet shall have appropriate identification and one-line diagram that applies to the specific portion of the system associated with time-current curves on that sheet.
				5. Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which device is proposed.
				6. Identify the device associated with each curve by manufacturer type, function, and if applicable, tap, time delay, and instantaneous settings recommended.
				7. Plot the following characteristics on curve sheets:

Electric utility’s relays and fuses (provided by utility).

Medium voltage switchgear relays.

Medium voltage equipment relays.

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

Low voltage equipment circuit breaker trip devices, including manufacturer’s tolerance bands.

Pertinent transformer full-load currents at 100 and 600 percent.

Transformer magnetizing inrush currents.

Transformer damage curves.

ANSI transformer withstand parameters.

Significant symmetrical and asymmetrical fault currents.

Ground fault protective device settings.

Curves shall be made distinguishable (in color and/or pattern) such that where overlapping occurs, individual curves can be discerned.

* + - * 1. Primary Protective Device Settings for Delta-Wye Connected Transformer:

Secondary Line-To-Ground Fault Protection: Provide primary protective device operating band within the transformer’s characteristics curve, including a point equal to 58 percent of ANSI C57.12.00 withstand point.

Secondary Line-To-Line Faults: Provide 16 percent current margin between primary protective device and associated secondary device characteristic curves.

* + - * 1. Separate medium voltage relay characteristics curves from curves for other devices by at least 0.4‑second time margin.
			1. ARC FLASH HAZARD ANALYSIS
				1. The Contractor’s arc flash study shall determine:

Arc flash incident energies.

Arc flash boundaries.

Shock hazard boundaries

Personal protective equipment (PPE) for energized electrical equipment.

Arc reducing protection schemes such as a zone selective interlocking, where installed, and maintenance switches, where installed, shall provide two labels on the gear for both positions of the switch.

* + - * 1. The arc flash study shall provide following information for each system mode of operation and shall be documented. The study results shall include:

Equipment name and voltage.

Equipment device name and ANSI function (i.e., 51/50).

Equipment type, i.e., switchgear, MCC, panel, VFD, etc.

Equipment arc gap.

Bolted and estimated arcing fault current at the fault point (equipment) in symmetrical amperes. The estimated arcing current shall be based on the arcing current equations used.

Trip time, opening time, and total clearing time (total arc time) of the protective device.

Worst-case arc flash boundary for each bus/equipment in the model.

Worst-case arc flash hazard incident energy in cal/cm2 for each bus/equipment in the model.

Worst-case PPE for each bus/equipment in the model.

Working distances for up to five different distances showing items 7, 8, and 9 for each distance.

Indicate “Danger/Hazardous” areas where incident energy is greater than 40 cal/cm2 and provide recommendations to reduced arc flash energy levels for these areas.

Flag results where 85 percent arcing current provided worst-case results.

Flag where the calculations are time limited (i.e., where a 2 second maximum burn time was implemented).

Description of installed arc flash equipment protection (i.e. zone selective interlock, maintenance settings, differential, or modified differential).

* + - * 1. Report format:

Introduction.

Methodology.

Back up information.

Key assumptions.

IEEE 1584-2002 considerations.

Arc flash reduction options: Overcurrent protective device changes.

Explanation of data in arc flash hazard report tables.

NFPA 70E Information.

Shock hazards with covers removed.

Shock hazard approach boundaries.

Limited approach boundary.

Restricted approach boundary.

Prohibited approach boundary.

Arc flash hazard boundaries.

Results of arc flash hazard analysis for high voltage, medium voltage and low voltage systems, including:

Working distances.

Energy levels.

PPE requirements.

Recommendations to reduce arc flash hazard energy and exposure.

Arc flash hazard report.

Electronic file.

* + - * 1. Provide arc flash warning labels as shown in the sample at the end of this section. An electronic copy of the EasyPower arc flash label template will be provided by the Port upon request.
			1. TABULATIONS
				1. General data shall include:

Load summary.

Cable and conduit material data.

Bus data.

Transformer data.

Circuit resistance and reactance values.

* + - * 1. Short circuit data shall include:

Fault impedances.

X to R ratios.

Asymmetry factors.

Motor contributions.

Short circuit kVA.

Symmetrical and asymmetrical fault currents.

* + - * 1. Include recommended protective device settings for:

Fuses:

Types.

Ratings.

Breakers.

* + - 1. ANALYSIS SUMMARY
				1. Provide a written summary that includes:

Scope of studies performed.

Explanation of bus and branch numbering system.

Prevailing conditions.

Selected equipment deficiencies.

Results of short circuit, coordination, and arc flash studies.

Comments or suggestions.

* + - * 1. Suggest changes and additions to equipment rating and/or characteristics.
				2. Notify the Port in writing of existing circuit protective devices improperly rated for new fault conditions.
1. PRODUCTS

Not Used.

1. EXECUTION
	* + 1. GENERAL
				1. Make minor modifications to equipment as required to accomplish conformance with the short circuit and protective device coordination studies. Perform field adjustments of the protective devices as required to place the equipment in final operating condition. The setting shall be in accordance with the protective device evaluation and protective device coordination study.
				2. Necessary field settings of devices, adjustments, and minor modifications to equipment to accomplish conformance with the approved protective device coordination study shall be performed by the Contractor at no additional cost to the Port.
				3. Notify the Port in writing of any required major equipment modifications.
				4. Provide recommended fuses of the types and ratings recommended by the studies after coordinating with and obtaining approval from the Port.
			2. FUNCTIONAL ACCEPTANCE SURVEY
				1. Field verify and record device settings on all adjustable protective devices. Compare all field settings with the recommended set points listed in the study and resolve any settings.
				2. Provide study results.
				3. Verify arc-flash labels are installed. Verify “series” rating labels are installed if approved.
				4. Provide updated electronic copy of Easy Power models to the Port. Model shall be returned with all modified areas highlighted in blue.
				5. Summarize differences between the recommended set points and final set points.

SAMPLE ARC FLASH LABEL



END OF SECTION 260573