SECTION 260573.16 - COORDINATION STUDIES

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

1. GENERAL
	* + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
			1. SUMMARY
				1. Section includes computer-based, overcurrent protective device coordination studies to determine overcurrent protective devices and to determine overcurrent protective device settings for selective tripping.

If retaining subparagraph below, indicate series-rated devices on Drawings. See the Evaluations for discussion of series rating.

Study results shall be used to determine coordination of series-rated devices.

* + - 1. DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

* + - * 1. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed, and salvaged, or removed and reinstalled. Existing to remain items shall remain functional throughout the construction period.
				2. Field Adjusting Agency: An independent electrical testing agency with full-time employees and the capability to adjust devices and conduct testing indicated and that is a member company of NETA.

Definition of "One-Line Diagram" Paragraphparagraph below is from NEMA ICS 19.

* + - * 1. One-Line Diagram: A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.
				2. Power System Analysis Software Developer: An entity that commercially develops, maintains, and distributes computer software used for power system studies.
				3. Power System Analysis Specialist: Professional engineer in charge of performing the study and documenting recommendations, licensed in the state where Project is located.
				4. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion of the circuit from the system.
				5. SCCR: Short-circuit current rating.
				6. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.
				7. Single-Line Diagram: See "One-Line Diagram."
			1. SUBMITTALS
				1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.
				2. Manufacturer’s installation instructions shall be provided along with product data.
				3. Submittals shall be provided in the order in which they are specified and tabbed (for combined submittals).

Coordinate this article with submittal requirements retained in Section 013300 "Submittal Procedures."

* + - * 1. Product Data:

For computer software program to be used for studies.

Submit the following after the approval of system protective devices submittals. Submittals [**shall**] [**may**] be in digital form.

Coordination-study input data, including completed computer program input data sheets.

Study and equipment evaluation reports.

Requiring submittal of the following coordination study does not relieve Engineer from responsibility for a preliminary coordination study to ensure that the system overcurrent protection can be coordinated. This submittal confirms that actual equipment in use, along with types and lengths of cables that will be installed, perform as system was designed.

Overcurrent protective device coordination study report; signed, dated, and sealed by a qualified professional engineer.

Submittal of the report prior to final approval of equipment requires some level of confidence that equipment will be approved, because the purpose of this study submittal is to confirm that coordination of exact equipment to be installed meets requirements. There is a balancing act of early submission of the study so equipment can be ordered, and the risk that equipment the study is based on will not be approved.

Submit 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 for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.

* + - * 1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

* + - * 1. Qualification Data:

For Power System Analysis Software Developer.

For Power Systems Analysis Specialist.

For Field Adjusting Agency.

Retain "Product Certificates" Paragraphparagraph below to require submittal of product certificates from manufacturers.

* + - * 1. Product Certificates: For overcurrent protective device coordination study software, certifying compliance with IEEE 399.
			1. CLOSEOUT SUBMITTALS
				1. Operation and Maintenance Data: For overcurrent protective devices to include in emergency, operation, and maintenance manuals.

The following are from the Coordination Study Report:

Final one-line diagram.

Final protective device coordination study.

Coordination study data files.

List of all protective device settings.

Time-current coordination curves.

Power system data include information on available short-circuit current at line terminals of equipment, which are Contractor's responsibility. This information may be data from the utility or a campus-style network. It may also include O&M data on existing equipment in system.

Power system data.

* + - 1. QUALITY ASSURANCE
				1. Studies shall be performed using commercially developed and distributed software designed specifically for power system analysis.
				2. Software algorithms shall comply with requirements of standards and guides specified in this Section.
				3. Manual calculations are unacceptable.
				4. Power System Analysis Software Qualifications:

Computer program shall be designed to perform coordination studies or have a function, component, or add-on module designed to perform coordination studies.

Computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

See the Evaluations for guidance on retaining "Power Systems Analysis Specialist Qualifications" Paragraphparagraph below.

* + - * 1. Power Systems Analysis Specialist Qualifications: Professional engineer licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional engineer.

See the Evaluations for data on qualifications of Field Adjusting Agency.

* + - * 1. Field Adjusting Agency Qualifications:

Employer of a NETA ETT-Certified Technician Level III responsible for all field adjusting of the Work.

A member company of NETA.

Acceptable to authorities having jurisdiction.

1. PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

* + - 1. POWER SYSTEM ANALYSIS SOFTWARE DEVELOPERS
				1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

EasyPower, LLC (formerly ESA Inc.).

Power Analytics, Corporation.

SKM Systems Analysis, Inc.

Or equal.

* + - * 1. Comply with IEEE 242 and IEEE 399.
				2. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.
				3. Computer software program 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.

See the Evaluations for discussion of optional features.

Optional Features:

Retain first subparagraph below if software used for this study should have capability of arc-flash studies. See the Evaluations for more information.

Arcing faults.

Simultaneous faults.

Explicit negative sequence.

Mutual coupling in zero sequence.

* + - 1. COORDINATION STUDY REPORT CONTENTS

In this article, retain only paragraphs that are needed to achieve objectives of the overcurrent protective device coordination. If study objective is to also evaluate SCCR of overcurrent protective devices, then retain relevant paragraphs below.

* + - * 1. Executive summary of study findings.
				2. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.
				3. One-line diagram of modeled power system, showing the following:

Protective device designations and ampere ratings.

Conductor types, sizes, and lengths.

Transformer kilovolt ampere (kVA) and voltage ratings.

Motor and generator designations and kVA ratings.

Switchgear, switchboard, motor-control center, and panelboard designations.

Any revisions to electrical equipment required by the study.

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

Short-Circuit Study Output: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents" Article in Section 260573.13 "Short-Circuit Studies."

* + - * 1. Protective Device Coordination Study:

Report recommended settings of protective devices, ready to be applied in the field. Use manufacturer's data sheets for recording the recommended setting of overcurrent protective devices when available.

Phase and Ground Relays:

Device tag.

Relay current transformer ratio and tap, time dial, and instantaneous pickup value.

Recommendations on improved relaying systems, if applicable.

Circuit Breakers:

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

Adjustable time-current characteristic.

Adjustable instantaneous pickup.

Recommendations on improved trip systems, if applicable.

Low-voltage fuse classes are defined in UL 248-1 through UL 248-18. Medium-voltage fuses are defined in IEEE C37.40.

Fuses: Show current rating, voltage, and class.

* + - * 1. Time-Current Coordination Curves: Determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists between devices installed in series, including power utility company's upstream devices. Prepare separate sets of curves for the switching schemes and for emergency periods where the power source is local generation. Show the following information:

Device tag and title, one-line diagram with legend identifying the portion of the system covered.

Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device is exposed.

Identify the device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.

Plot the following listed characteristic curves, as applicable:

Power utility's overcurrent protective device.

Medium-voltage equipment overcurrent 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.

Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.

Cables and conductors damage curves.

Ground-fault protective devices.

Motor-starting characteristics and motor damage points.

Generator short-circuit decrement curve and generator damage point.

The largest feeder circuit breaker in each motor-control center and panelboard.

Series rating on equipment allows application of two series interrupting devices for a condition where the available fault current is greater than the interrupting rating of downstream equipment. Both devices share in interruption of the fault, and selectivity is sacrificed at high fault levels.

Maintain selectivity for tripping currents caused by overloads.

Maintain maximum achievable selectivity for tripping currents caused by overloads on series-rated devices.

Provide adequate time margins between device characteristics such that selective operation is achieved.

Comments and recommendations for system improvements.

1. EXECUTION
	* + 1. EXAMINATION
				1. 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.

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.

* + - 1. POWER SYSTEM DATA

This article lists data needed to conduct the overcurrent protective device coordination study. Delete data already indicated on one-line diagram; add data that should be considered in study results. Verify short-circuit study data if a short-circuit study has been completed prior to or separate from the coordination study. See Section 260573.13 "Short-Circuit Studies" if a short-circuit study is necessary.

* + - * 1. Obtain all data necessary for conduct of the overcurrent protective device study.

Verify completeness of data supplied in one-line diagram on Drawings. Call any discrepancies to Architect's attention.

For equipment included as Work of this Project, use characteristics submitted under provisions of action submittals and information submittals for this Project.

For [**equipment that**] [**relocated equipment and that which**] is existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers. Qualifications of technicians and engineers shall be as defined by NFPA 70E.

* + - * 1. Gather and tabulate all required input data to support the coordination study. List below is a guide. Comply with recommendations in IEEE 551 for the amount of detail required to be acquired in the field. Field data gathering shall be under direct supervision and control of the engineer Director’s Representative in charge of performing the study and shall be by the engineer Director’s Representative or its representative who holds NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification. Data include, but are not limited to, the following:

Product Data for overcurrent protective devices specified in other Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.

Electrical power utility impedance at the service.

Power sources and ties.

Short-circuit current at each system bus (three phase and line to ground).

Full-load current of all loads.

Voltage level at each bus.

For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.

For reactors, provide manufacturer and model designation, voltage rating, and impedance.

For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip and available range of settings, SCCR, current rating, and breaker settings.

Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.

For relays, provide manufacturer and model designation, current transformer ratios, potential transformer ratios, and relay settings.

Maximum demands from service meters.

Busway manufacturer and model designation, current rating, impedance, lengths, size, and conductor material.

Motor horsepower and NEMA MG 1 code letter designation.

Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).

Medium-voltage cable sizes, lengths, conductor material, cable construction, metallic shield performance parameters, and conduit material (magnetic or nonmagnetic).

Data sheets to supplement electrical distribution system one-line diagram, cross-referenced with tag numbers on diagram, showing the following:

Special load considerations, including starting inrush currents and frequent starting and stopping.

Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.

Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.

Generator thermal-damage curve.

Ratings, types, and settings of utility company's overcurrent protective devices.

Special overcurrent protective device settings or types stipulated by utility company.

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

Manufacturer, frame size, interrupting rating in amperes root mean square (rms) symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.

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

Switchgear, switchboards, motor-control centers, and panelboards ampacity, and SCCR in amperes rms symmetrical.

Identify series-rated interrupting devices for a condition where the available fault current is greater than the interrupting rating of downstream equipment. Obtain device data details to allow verification that series application of these devices complies with NFPA 70 and UL 489 requirements.

* + - 1. COORDINATION STUDY
				1. Comply with IEEE 242 for calculating short-circuit currents and determining coordination time intervals.
				2. Comply with IEEE 399 for general study procedures.
				3. Base study on device characteristics supplied by device manufacturer.

Coordinate first two paragraphs below with Drawings. See the Evaluations for discussion on one-line diagram.

* + - * 1. Extent of electrical power system to be studied is indicated on Drawings.

See the Evaluations for discussion of what data should be indicated on one-line diagram, where the study should stop, and what data should be obtained and verified by Contractor.

* + - * 1. Begin analysis at the service, extending down to system overcurrent protective devices as follows:

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

Retain first subparagraph below when authorities having jurisdiction do not require inclusion of all equipment.

Exclude equipment rated 240 V ac or less when supplied by a single transformer rated less than 125 kVA.

<**Insert description**>.

* + - * 1. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.
				2. Transformer Primary Overcurrent Protective Devices:

Device shall not operate in response to the following:

Inrush current when first energized.

Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.

Permissible transformer overloads according to IEEE C57.96 if required by unusual loading or emergency conditions.

Device settings shall protect transformers according to IEEE C57.12.00, for fault currents.

* + - * 1. Motor Protection:

Select protection for low-voltage motors according to IEEE 242 and NFPA 70.

Select protection for motors served at voltages more than 600 V according to IEEE 620.

* + - * 1. Conductor Protection: Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and protection recommendations in IEEE 242. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary relay protection or total clearing time of the fuse. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.
				2. Generator Protection: Select protection according to manufacturer's written instructions and to IEEE 242.
				3. Include the 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.
				4. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault and a single line-to-ground fault at each equipment indicated on one-line diagram.

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.

* + - * 1. Protective Device Evaluation:

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

Adequacy of switchgear, motor-control centers, and panelboard bus bars to withstand short-circuit stresses.

See "Coordination Study" Article in the Evaluations for a discussion of series-rated devices.

Any application of series-rated devices shall be recertified, complying with requirements in NFPA 70.

Include in the report identification of any protective device applied outside its capacity.

* + - 1. LOAD-FLOW AND VOLTAGE-DROP STUDY
				1. Perform a load-flow and voltage-drop study to determine the steady-state loading profile of the system. Analyze power system performance two times as follows:

Determine load flow and voltage drop based on full-load currents obtained in "Power System Data" Article.

Determine load flow and voltage drop based on 80 percent of the design capacity of load buses.

Prepare load-flow and voltage-drop analysis and report to show power system components that are overloaded or might become overloaded; show bus voltages that are less than as prescribed by NFPA 70.

* + - 1. MOTOR-STARTING STUDY
				1. Perform a motor-starting study to analyze the transient effect of system's voltage profile during motor starting. Calculate significant motor-starting voltage profiles and analyze the effects of motor starting on the power system stability.

Objectionable light flicker and voltage sags are occupancy dependent. See the Evaluations for a discussion of IEEE standards, and insert additional requirements on reporting study results based on Project requirements.

* + - * 1. Prepare the motor-starting study report, noting light flicker for limits proposed by IEEE 141, and <**Insert applicable standards**>, and voltage sags so as not to affect operation of other utilization equipment on system supplying the motor.
			1. FIELD ADJUSTING
				1. Adjust relay and protective device settings according to recommended settings provided by the coordination study. Field adjustments shall be completed by the engineering service division of equipment manufacturer under the "Startup and Acceptance Testing" contract portion.
				2. Make minor modifications to equipment as required to accomplish compliance with [**short-circuit and**]protective device coordination studies.

See the Evaluations for data on qualifications of Field Adjusting Agency.

* + - * 1. Testing and adjusting shall be by a full-time employee of the Field Adjusting Agency, who holds NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification.

Retain subparagraph below with one of last two paragraphs above. Revise to suit Project. Delete subparagraph if testing is performed by Owner-engaged testing and inspecting agency.

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

* + - 1. DEMONSTRATION

See Section 017900 "Demonstration and Training" for requirements to train Owner's maintenance personnel to adjust, operate, and maintain overcurrent protective devices.

* + - * 1. Engage Power Systems Analysis Specialist to train Director’s Representative's maintenance personnel in the following:

Acquaint personnel in fundamentals of operating the power system in normal and emergency modes.

Hand-out and explain the coordination study objectives, study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpreting time-current coordination curves.

For Director’s Representative's maintenance staff certified as NETA ETT-Certified Technicians Level III or NICET Electrical Power Testing Level III Technicians, teach how to adjust, operate, and maintain overcurrent protective device settings.

END OF SECTION 260573.16