

Electrical System Commissioning

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AIA Quality Assurance



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Course Description

The commissioning provider is expected to confirm that the building's electrical systems are installed per design requirements and are operational in accordance with the design documents, approved submittals, and vendors IO&M data. This commissioning can include normal power, emergency power, UPS, Lighting and On-site generation.

This course will instruct the commissioning provider on their role in the design, installation, energization, acceptance and functional testing of electrical systems. It will outline the steps in the commissioning process, from contract award to commissioning turnover. It will provide for general installation checks and functional tests. The course will help to identify possible issues and resolutions to issues during each step of commissioning.

Learning Objectives

1. Understand the steps in electrical system commissioning.
2. Understand the role of the commissioning provider in the design and installation of the electrical systems.
3. Identify the general installation checks for electrical systems.
4. Identify commissioning's role during the acceptance testing and functional testing and how to interface with the electrical contractors and vendors during the commissioning process and the limitations on the commissioning provider during the acceptance testing and functional testing.

The Commissioning Steps

- Advisor the Owner (things don't just happen) Review project, goals and commissioning scope
- Project Kick-Off Meeting, after project award.
- Investigation support (existing electrical systems, tie-ins and operations, if required).
- Meetings to review and address findings, if required.
- OPR and BOD development and review. Support as needed.
- Design Reviews. Schematic, Design Development, Construction Documents and Bulletins.
- Commissioning Plan Development
- Meetings with the contractors to review the plan
- Meet with construction team. Review contracts with CM and Subs. (Who own's what?)
- Submittals Reviews (can include factory acceptance tests (FAT) and site acceptance tests (SAT)).
- IO&M Reviews

The Commissioning Steps

- Identify any gaps from basis of design (BOD) and specifications.
- Generation and execution of installation checks and/or PFC completion reviews.
- Witness electrical tests by contractors and vendors.
- Close out open items or issues in the installation.
- Identify safety requirements.
- Generate and execute functional testing.
- Generate and execute Integrated testing of systems.
- Identify and resolve issues.
- Issue commissioning reports and final commissioning report.
- Commissioning turnover.
- Support for future system operations – Training and Acceptance

Site Review – Existing Buildings

- Review existing system and equipment. Has it been maintained. Any open PM items for the Switchgear, Automatic Transfer Switch (ATS), Distribution Panels. Has any testing been completed.
- Is Megger Testing of the existing wiring required? Should it be?
- Review any service paperwork.
- Interview the staff. Do you know the electrical system? Do they understand items like the use of Tie Breakers, and electronic controls for serves entry gear.
- Any ongoing issues?
- Any problems with the generators or ATSSs?
- General issues with gear, transformers, panels, breakers, etc.
- Identify how any existing electrical system may impact the Owner's Project Requirements (OPR) and Basis of Design (BOD).
- Meet to review finding, issues and plan for resolution
- Verify resolution of issues.

Project Documentations - OPR

- Support the development of the Owner's Project Requirements (OPR) that includes general requirements for the electrical systems, outlining the types of systems and equipment, the expected size and function of those systems and the minimum requirements for operation and monitoring of the electrical systems.
- What standard was used BCXA, IEEE, ASHRAE?
- Does the OPR indicate what systems are on uninterruptable power source (UPS), E-Power, or other key owner's requirements
- Does it address minimum capacity, redundancy and quality for system and equipment?
- Does it include requirements for power conditioners, surge suppressors, voltage regulators, isolation transformers?

Project Documentations - OPR

- Does it cover lighting and controls, daylighting?
- Does it cover codes and standards for the electrical systems?
- Does it cover energy usage or energy conservation?
- Does it cover any onsite generation?

Project Documentation - BOD

- Review the basis of design (BOD) to assure it complies with the OPR requirements, provides the required details of the electrical systems, and identifies the codes and standards to be used during the design development and construction documentation phases of the project.
- Does it include a narrative description of the power distribution system?
- Review the BOD to verify it includes acceptance criteria.
- Review the BOD to confirm the power requirements and supply information meet the OPR?
- Does it include design approach and criteria.
- Does it include estimated loads?
- Does it include quality control criteria?
- Does it address any hazardous areas, or area classification?
- Does it address lighting, grounding, lightning protection?

Project Documentation - BOD

- Does it include commissioning requirements?
- Does it include contractor support requirements?
- Does it include the Arc Flash, Short Circuit and Breaker Coordination Study.

Pre - Design Review

- The commissioning provider should have a knowledge of the NEC and NETA.
- The commissioning provider should have a knowledge of local codes and standards.
- The commissioning provider should understand electrical distribution for buildings, system and equipment.
- The commissioning provider should understand normal power systems.
- The commissioning provider should understand emergency power, standby power, and UPS systems.
- The commissioning provider should understand lighting and controls.
- The commissioning provider should understand on site power generation.
- The commissioning provider should have knowledge of lock-out/tag out (LOT) procedures.
- Not just a “show-up” and execute a check or test.

Design Review - General

- Review the design documents per the commissioning requirements. Confirm they are in line with the BOD and provide enough detail to allow the start of commissioning documentation.
- Assure the specifications include the requirements to support the commissioning process and the required demonstration that will be provided by the sub-contractors and vendors. Refer to ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems (ANSI/NETA ATS).
- Review the design drawings. Do the electrical drawings match the mechanical, plumbing, process drawings. Is all equipment accounted for? Note that bulletins may impact your review.
- Review the design drawings. Confirm the design drawings and specifications align.
- Review installation details. Look for seismic restraint and vibration isolation.
- Look for drawing notes that should be covered in specification or impact the construction of the systems.

Design Review - General

- Review the single lines and the panel schedules. Verify the distribution and equipment power requirements are addressed in the design.
- Review to understand the requirements for normal, UPS and E-Power.
- Check that BAS and other controllers are part of the system. Items like elevators should be checked.
- Review the drawings to assure that the required access and clearances are provided for the electrical equipment.
- Check lighting and lighting controls. Some areas may be on E-power, some may be battery powered.

Design Review - General

- Review the specification. Check to make sure they align with the BOD. Confirm the test requirements are outlined in the specs. Recommend additional items if you feel they were missed. Tests like panel load adjustment, and inferred testing may take place after initial energization and even much later in the project. Note that items like sound levels may be part of the specs.
- Was factory testing required?
- Are power studies required?
- Are short circuit studies required?
- Are protective device evaluation and coordination studies required?
- Are flash protection studies required?
- Are UL or FM labels required?
- Review for warranty requirements.

Design Review – Normal Power

- Review the normal power single line drawing.
- What type of incoming service is provided? Single service, two or more services?
- What tie-ins are available, tie breakers or parallel gear?
- Does the normal power distribution feed all the equipment from the mechanical, plumbing, FA, FP and additional systems?
- Check for normal power feeds to ATS (s).

Design Review – Emergency/Standby/UPS

- Understand and review for the requirements of emergency power system, UPS, standby system loads.
- Review the emergency load estimate and emergency riser diagrams.
- Review the generator, ATS (and bypass), UPS and equipment locations.
- Review the required controls, monitoring and notification systems.
- Review the generator paralleling switchgear design. Understand how it operates and how it should be commissioned.
- Review power feed pathways and installation design. (Trenches, Poles, etc.)

Design Review – Emergency/Standby/UPS

- Review access to generators and gear. Will this require guard rails, bollards, ladders, or tie-off points. Safety always comes first.
- Review any access requirements that require permitting, like confined space access. Can this be avoided?
- Review Cable/Wire Specifications.
- Review for any additional fire alarm/fire protection requirements. This includes FA tie-ins and additional sprinkler requirements.
- Review design for phasing requirements. Understand the impact on commissioning and system operation and turn-over. Will generation be added as load is added?

Final Design Review

- Verify all comments from design reviews have been addressed.
- Review the updated specifications.
- Review the updated riser and one-line diagrams.
- Double check the completed design calculations and load summaries.

Design Review – Possible Issues

- Not enough information to completed commissioning documents.
- Mismatch between mechanical, plumbing and electrical systems.
- Final design does not include all comments from schematics, design development issues.
- Missing UPS system. Some systems require it others do not.
- Missing or incomplete design information (Signal lines, details, load calculations)
- Missing or incomplete power control sequences, staging or load addition.
- Missing or incomplete BAS sequences, lockouts, load shedding, delayed restart.
- Missing testing and acceptance requirements in specifications.
- Missing vendor and contractor support requirements in specifications.

Commissioning Plan

- Develop the commissioning plan based on the systems and equipment being installed and scope of commissioning based on the contract documents.
- Review the specifications to confirm that the commissioning plan incorporates the installation checks and operational tests outlined in the specifications.
- Review the contracts to confirm that the plan only includes checks and testing within the contract language.
- The plan should outline the steps required for commissioning of the electrical systems.
- The plan should include identification of hazards and controls used during commissioning.
- It should identify the installation checks and functional test requirements.

Commissioning Plan

- It should identify team members and role and responsibilities.
- It should identify support requirements.
- It should include what is being commissioned, who own's checks and tests.
- It should identify the contractor's acceptance test requirements.
- It should address how testing is completed.
- It identifies how to resolve deficiencies.
- It should identify LOTO requirements based on project standards (may be OSHA)
- It should include documentation requirements and training requirements.
- It should include the format for documentation (CxAlloy, Paper, other).
- It should identify turnover requirements.

Submittal Review

- Is there a submittal log and did the commissioning provider review?
- Are the submittals complete, or just cut sheets?
- Do the submittal provided the required information need to write and execute commissioning documents?
- Review the “approved” submittals. Review in parallel may lead to some conflicts. Let the A/E take the lead.
- Confirm the submittals match the drawings and specifications and look for any exclusions in the submittals.
- Check for any interoperability between systems and equipment.
- Check to see if there are additional requirements outlined in submittals that may not be in the design documents.
- Review any FAT and or SAT documents.

Submittal Review

- Check for support and access requirements.
- Review the submittals for the panel and transformers.
- Review the submittals for: Emergency Generators, Switchboards, Automatic Transfer Switches, UPS, generator paralleling switchgear and distribution panels.
- Review the control logic for system start-up, staging, and transfer.
- Review the power monitoring.
- Review the notification system.
- Review fuel sources.
- IO&M information should be included in the submittals. Not just cut sheets.
- Are training requirements part of the submittals?

Possible Issues

- Missing, Incomplete or Inaccurate submittals.
- Missing performance data.
- Submittals with “approved as noted” that change the design or operational requirements. Need Record Submittals.
- Missing UPS power.
- Missing safety items.
- Insufficient information on Lighting or lighting controls.
- Lighting controls not tied into or monitored by the BAS.

Generate Installation Check Documents

- Generate checks from the Single Line, Panel Schedules, and Equipment Schedules.
- Generate checks using the approved submittals shop drawings, CD's and IO&Ms.
- Checks may be based on Specifications, Site/Project Standards, NEC/NETA or other standards (technical manuals).
- Checks may be leveraged from vendor provided checklists.
- Review RFIs, make sure they don't impact commissioning.

Generate Installation Check Documents

- Include nameplate checks.
- Include checks for clearances and access.
- Include checks for damage, deficiencies.
- Include component checks.
- Include system/equipment completion checks. (site assembled/stick-built systems)
- Include any checks from IO&Ms.
- Include field installed items like filters.
- Include checks for lubrication.

Generate Installation Check Documents

- Include lighting and lighting controls.
- Include lightning protection.
- Include any on-site generation systems. (solar, wind, etc.)
- Include controls checks, programmable logic controller (PLC), human-machine-interface (HMI), Gauges, Instruments, Lights, ETC.

Execute Installation Checks

- Coordinate with the CM/GC.
- Coordinate with the EC and Vendors.
- Review schedule. What can or will be energized?
- Check for required LOTO. (energized system and equipment)
- Identify any issues or open items that may impact your checks.
- Check Nameplate Data.
- Check for damage or defects.
- Check area and equipment for cleanliness.
- Check clearances and access.
- Check for equipment and system completeness.
- Check conduit runs.
- Check for grounding.

Execute Installation Checks

- Verify electrical equipment matches the approved submittals. Check accessories against the submittals.
- Review for damage or defects. Note this may need to include for possible hazards due to rotating equipment and pinch-points.
- Check clearances and access.
- Review installation against shop drawings, CD's and IO&Ms.
- Review all service piping, utility piping, valves and accessories.

Execute Installation Checks

- Check for field installed items like Generator Silencer.
- Check access requirements, ladders, guard rails.
- Check lighting and lighting controls.
- Check the on-site generation systems.
- Check UPS power.
- Check the Power Monitoring System.
- Check the operator's interface or touchscreen.

Possible Issues

- Incomplete installation.
- Missing panel, covers, blank-offs, or screws.
- Missing grounding.
- Damaged PLC/HMI, gauges.
- Damaged and/or missing breakers.
- Equipment not secured.
- Equipment not fueled or not lubricated.

Coordinate Testing

- Review the pre-energization safety checklists.
- All equipment tagged.
- Switches open and checked.
- Review the LOTO.
- Communications defined and notification completed.
- Exits are clear.
- Barriers in place.
- PPE requirements are defined.
- Arc Flash (blast) radius identified.
- Environmental conditions checked.

Who Executes Testing

- The contractors are qualified to perform all aspects of the testing, are responsible for assuring the installation meets the NEC standards, and responsible to comply with the AHJ, to include AHJ inspections and closing out of permits.
- Per NEC and NETA, Technicians shall be certified in accordance with ANSI/NETA ETT-2000, Standard for Certification of Electrical Testing Personnel. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.
- Limited Approach Boundary - The Limited Approach Boundary (LAB) is identified as the "distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists". Best practice is for any unqualified person to stay 42" (3' 6") or more away from the hazard.
- The term "qualified person," is defined by NFPA 70E as, "one who has demonstrated skill and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved."

Witness Contractor and Vendor Testing

- Contractor and vendor acceptance testing generally is the heart of the electrical testing process.
- All equipment specified for testing should be subject to electrical tests as well as cleaning, lubrication, visual inspection, and exercising. All tests should be performed per applicable NETA, IEEE, NFPA 70B, and Engineering guidelines.
- The contractor and vendor documents used should be reviewed and pre-approved and examples of completed tests should be provided.
- Review the steps and schedules.
- Meet with the contractors and testing firm.
- The commissioning provider should witness testing.

Witness Contractor and Vendor Testing

- Understand what testing has been covered in specifications, testing is based on the specification and contract documents.
- Understand what can be completed before energization, and what is done after energization.
- Review documents executed by the contractors and vendors.
- Document any failures, resolutions and any open items.

Witness Contractor and Vendor Testing

- May included: Grounding Test, Megger Tests, Hot-Pot Tests, Interlock Tests, Phase Tests, Transformer Tests.
- May include Controls Tests and Monitoring Checks/Tests.
- May include Breaker setting checks (to be finalized later)
- May include Rotating equipment checks.
- May include Load Bank Testing for generators and UPS. Power loss Testing will follow.
- May include Lighting and lighting controls tests.
- May include Low voltage checks.
- May include On site power generation.

Possible Issues

- Incomplete documentation from the contractor and vendors.
- Incomplete equipment or system.
- Poor Mechanical Alignment, breakers not operational.
- Mis-wired circuits.
- Bad Relays.
- Missed Wired Controls.
- Grounding Issues.
- Incorrect trip settings.
- Sensors not calibrated.

Develop Functional Tests

- Develop tests not covered under acceptance testing.
- Develop tests that effect multiple systems or equipment.
- Develop test for inter-related systems, Electrical, Elevators, Fire Alarm, Fire Protection, and Access Controls.
- Develop additional tests for power generation. Additional, on-grid, off-grid and power failure tests, may include BAS.
- Develop tests for life safety system, even if they were checked.
- Develop a full building power loss test. This may be the last test done.
- Develop tests for energy saving (controlled receptacles, HVAC setback by lighting)

Execute Functional Tests – Qualified Person – NFPA/NEC

- **110.2(A)(1) Qualified Person.** A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.
- (a) Such persons shall also be familiar with the proper use of the special precautionary techniques, applicable electrical policies and procedures, PPE, insulating and shielding materials, and insulated tools and test equipment.
- (b) A person can be considered qualified with respect to certain equipment and tasks but still be unqualified for others.
- (c) Such persons permitted to work within the limited approach boundary shall, at a minimum, be additionally trained in all of the following:
 - (1) Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment
 - (2) Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts
 - (3) Approach distances specified in Table 130.4(D)(a) and Table 130.4(D)(b) and the corresponding voltages to which the qualified person will be exposed.
 - (4) Decision-making process necessary to be able to do the following:
 - a. Perform the job safety planning
 - b. Identify electrical hazards
 - c. Assess the associated risk
 - d. Select the appropriate risk control methods from the hierarchy of controls identified in 110.1(G), including personal protective equipment
- (d) An employee who is undergoing on-the-job training for the purpose of obtaining the skills and knowledge necessary to be considered a qualified person, and who in the course of such training demonstrates an ability to perform specific duties safely at his or her level of training, and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those specific duties.
- (e) Employees shall be trained to select an appropriate test instrument and shall demonstrate how to use a device to verify the absence of voltage, including interpreting indications provided by the device. The training shall include information that enables the employee to understand all limitations of each test instrument that might be used.
- (f) The employer shall determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard

Execute Functional Testing

- The level of detail is based on the information provided by the installers and supporting vendors.
- Incoming service tests, generator tests, ATS, UPS tests, power loss.
- Lighting and Controls testing.
- Execute tests not covered under acceptance testing.
- Execute tests that effect multiple systems or equipment.
- Execute test for inter-related systems, Electrical with: Elevators, Fire Alarm, Fire Protection and Access Controls.
- Execute tests for life safety system, even if they were checked.
- Execute a full building power loss test. This may be the last test done.
- Execute tests for energy saving (controlled receptacles, HVAC setback by lighting)

Possible Issues

- Poor Mechanical Alignment, breakers not operational.
- Mis-wired circuits.
- Bad Relays.
- Missed Wired Controls.
- Grounding Issues.
- Incorrect trip settings.
- Incorrect programming of controls.
- Bad sensors.

Address Issues and Document Open Items

- Did the testing meet the specifications? Any tests not provided? Notes.
- Review the Issues Log.
- Review any item not closed at the time of commissioning.
- Review the path forward, is there any commissioning role?

Training

- The CM, Contractors and vendors are responsible for training of the owner's staff.
- The CM, Contractors and vendors are responsible for developing the training plan, to include who is required to be trained, who is doing the training, when will training take place. Will it be recorded?
- The CM, Contractors and vendors are responsible for developing the training materials.
- The owner should provide a list of personnel required for training.
- The commissioning provider should review the training plan and documents.
- The commissioning provider can attend training if within the scope of the commissioning.

Turn Over

- Generate commissioning reports and turn over packages.
- Review CM turnover documents, Red-lines, IO&M, Spare Parts.
- Verify warranty information.
- 2018 IECC - Cx/FPT Compliance Checklist.
- LEED, WELL or other commissioning reporting activities.
- 10-12 Month Review.
- What is the plan and what is the path for turnover? What is "Ownership" in the mind of the owner and operational staff. When are they responsible for all operations?
- Confirm the maintenance firm or responsible party accepts ownership.
- Review all the above at the close out meeting.

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