**U.s. Energy Department**

**Federal Energy Management Program**

**Guidelines and Checklist for Commissioning and Government Acceptance of ESPC ENABLE Projects**

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***PLEASE READ THIS GUIDE BEFORE COMMISSIONING AND BEFORE USING THE PROJECT ACCEPTANCE CHECKLIST***

**ESPC ENABLE Project Acceptance Guide**

**Introduction:** This guidance and checklist will help you through the final steps of your ESPC ENABLE project including project acceptance. By accepting the work of the ESCO, you are confirming that the ECMs have been installed to the specifications of the contract and are ready to begin the performance period and initiate payments to the ESCO.

**Instructions:** Beginningon page 2 (Section A) of this document you will find 10 numbered steps to final project acceptance. Please read through each of the steps, as well as the related notes, to become familiar with this process. In **Attachment 1 – ESPC ENABLE Project Acceptance Checklist**, you will find a checklist that takes you through the 10 steps, breaking some steps out into multiple checks. Please use this sheet to ensure that you have met all of the acceptance requirements and received all necessary submittals from the ESCO before accepting the project. Section B of this document provides expanded guidance pertaining to inspection and commissioning of the project (one of the 10 steps in project acceptance)

[Text in red font requires you to input project-specific information].

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# A. ESPC ENABLE Project Acceptance Guide

1. ECM Installation: All Energy Conservation Measures (ECM) are installed in accordance with plans, specifications, standards, and other contract documents (sometimes by the Contractor, often by a subcontractor).

2. Inspection, testing and commissioning. All ECMs are inspected, brought on line, tested, and commissioned *interactively* with all related Government-owned or Contractor-installed ECMs. Again, the ECMs should be operating in accordance with the design, plans, specifications, standards and other contract documents and manufacturer’s recommendations. Individual ECMs may go through start-up and testing, but all interrelated ECMs must be installed prior to commissioning. The Agency and Contractor should be involved in the inspection and commissioning process along with their subcontractors. The agency technical representative (TR) should accompany the Contractor on these inspections and document in writing that he has witnessed the inspections. Expanded guidance pertaining to the commissioning process is provided in Section B of this document.

*Note: An agency may have more rigorous test and acceptance procedures defined in the Task Order*.

3. Punch list generation. A punch list is generated during inspection and commissioning to document deficiencies, items that need to be corrected, adjusted or replaced, and to track completion of punch list items as each is addressed.

4. Measurement and Verification. M&V post-installation measurements are taken and M&V protocols are in place; in all cases a post installation report is generated (all based on the M&V plan submitted). Given the nature of the ECM’s within the ENABLE program, it may be most efficient for a contractor to obtain the necessary post-installation M&V sample measurements immediately following equipment installation. It is recommended that the agency witness these measurements where feasible, however measurements could also be verified by the agency in conjunction with the inspection and commissioning activity identified in step 2.

*Note: If the task order does not require the post-installation report to be submitted prior to acceptance, it should come in within 30 days after project completion.*

5. 30-day Acceptance Test Period. Upon completion of the above items for the last installed ECM, the Contractor writes a letter to the contracting officer (CO) asking for the 30-day Acceptance Test period to begin (assuming all significant punch list items have been corrected). Other discrepancies may appear during this period. The Contractor should have them all corrected by the end of the 30-day period. If the discrepancy has the potential to reappear or if another 30-day period is warranted because of the criticality of the ECM, the CO has the right to ask for continuation of the Acceptance Test period.

*Note: Even if individual ECMs have been operating successfully after installation for several weeks or months, all ECMs are included in this “official” 30-day Acceptance Test period.*

## 6. Final submittals.

* Operation and maintenance manuals are provided.
* Operation and maintenance training is provided.
* Spare parts are provided or spare parts lists are provided.
* Post Installation Report is reviewed and approved. (Report submitted by contractor within 30 days after project completions and acceptance)
* Utility rebate inspections and paperwork is approved and submitted.

*Note: All this can happen during the 30-day Acceptance Test period or as individual ECMs are installed.* *Punch list items that do not relate to system and equipment Acceptance Test are often handled during this period also.*

7. Agreement on modifications/change orders. Frequently during construction, there are changes that occur to the work scope. Some are Government-requested changes and some are Contractor-generated. It must first be determined whether the “change” is already within the scope of what the Contractor covered in their proposal. Any changes to the TO amount, savings, payment schedule, etc., must be agreed upon and documented in a Modification to the TO. The Modification should be ready by the time of final acceptance.

*Note: Both the Government and the Contractor should track all changes made during TO implementation. It is most feasible to do one modification to the TO for all changes made just prior to accepting the project. It is important that the Contractor and government come to agreement quickly so that payments are not unduly delayed.*

8. Final contractor/government inspection. One final walk-through should be conducted with the Government representative. The ECMs should be fully operational, without deficiencies, and all other items should have been provided by now. The Acceptance Checklist (see below) is noted with dates for each item, and signed off by the TR and forwarded to the CO.

9. Government Acceptance. The CO signs the checklist, writes a letter to the Contractor accepting the project, enclosing a copy of the checklist, and stating that payments can begin.

*Note: It is an agency decision as to when they feel the project can be accepted. The process above outlines an approach consistent with the ENABLE ESPC task order with the project acceptance for all ECMs occurring at one point and invoicing starting after complete project acceptance. At agency discretion, the CO may accept a project even though minor punch list items or some services are not yet completed. The acceptance letter would document the outstanding items with a due date for completion.*

10. Invoicing. The Contractor may invoice starting with the month after receiving Government acceptance. For instance, if a project is accepted on May 31, the first invoice can be sent around June 30 for payment around July 30.

*Note: Agencies have sometimes agreed to provide payments on a quarterly or monthly basis, rather than annually. Any arrangement other than annual invoices must be agreed upon must be documented in the task order.*

# B. ESPC ENABLE Project Commissioning Guidelines

## 1. COMMISSIONING SCOPE AND OBJECTIVES

Commissioning can be defined as the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the project intent. Although there are different approaches to commissioning, the fundamental process provides quality assurance to confirm that each of the following standards are met for all equipment included in the project:

1. The products and components selected and installed meet project design criteria.
2. Products and components are installed in accordance with the engineer’s and manufacturer’s recommendations and design criteria.
3. Products and components are capable of meeting their published performance criteria.
4. If the project includes a system of several products and components, the integrated system is installed in accordance with the engineer’s design criteria. (Example the use of lighting controls in conjunction with lighting equipment)
5. All foreseeable items necessary for the components and systems to continue to operate as designed have been identified for inclusion in the Agency’s Operations and Maintenance (O&M) Manuals.
6. The training requirements are identified including all items that need to be discussed and reviewed with facility personnel in order for the project to continue to perform.

Commissioning also uncovers any operating deficiencies to be corrected in the existing equipment that interfaces with the new equipment. All systems installed as part of the ESPC ENABLE scope are covered by the commissioning scope.

## 2. COMMISSIONING PROCESS

The commissioning process spans all phases of the project, with specific steps assigned to each of the major phases of a typical project. Those commissioning steps can be summarized as follows:

|  |  |
| --- | --- |
| **Project Phase** | **Commissioning Process Step** |
| Pre-IGA | Agency Project Requirements Review |
| IGA/Final Proposal | Project Design (Design Submittals/Review/Approval) |
| Installation | Acceptance Testing |
| Post Installation | End User Training / Systems Manuals |

### 2.1 Agency Project Requirements

The first step in the Commissioning Process is to further refine the Agency’s project requirements as initially defined in the Scope of Work (SOW). It is suggested that these requirements be captured as a formal pre-IGA commissioning document—typically by the Agency—providing clear expression of Agency’s requirements and expectations. The ESCO may also assist the Agency in refining the requirements and in addressing topics initially overlooked for consideration. (The requirements, however, may be vague until the IGA phase). This document provides a common reference point for the entire design and construction process.

As an example, requirements pertaining to lighting systems (in addition to energy efficiency) may include information about required tasks, special applications, architectural constraints, light levels, color, visual comfort, aesthetics, maintenance, technology, applicable codes and standards, and other issues.

### 2.2 Project Design

The Agency project requirements form the foundation of the project design or design intent. The Agency and ESCO may wish to capture elements of this step with a formal documentation of the agreed upon strategies. The document may include descriptions of systems, cover issues such as energy efficiency targets, desired technologies, preferred manufacturers, flexibility, maintenance requirements and level of training users will need to operate the controls.

**Note:** Federal agencies are required to purchase ENERGY STAR-qualified products or “FEMP-Designated” product categories where such categories have been established. It is recommended that the Agency establish with the ESCO the design requirement and a means of reviewing proposed products for compliance with the regulatory requirement. More information regarding the procurement requirement can be found at the DOE FEMP website under “Energy-Efficient Product Procurement” (https://www1.eere.energy.gov/femp/technologies/procuring\_eeproducts.html).

**Note:** DOE FEMP recommends that federal agencies consider a series of market-driven technologies in addressing their energy requirements that may be new or underutilized in the federal sector. Information on these technologies may be found at the DOE FEMP Technology Deployment web site: (https://www1.eere.energy.gov/femp/technologies/new\_technologies.html)

Over the course of the IGA phase, the design of the project, general concepts and strategies will become more and more detailed. The project’s final design is presented to the Agency in the form of a final proposal for the Agency’s review. The Agency should review the final proposal to ensure the established project requirements are being satisfied.

### 2.3 Acceptance Testing

Acceptance testing (also called performance testing or field commissioning) is conducted during or just after the installation phase, typically by the installing contractor and witnessed by the Agency, to ensure what goes into the building produces desired outcomes.

The ESCO is to generate a Commissioning Checklist for use in the acceptance-testing phase for which the following activities will be conducted:

• Installation verification to confirm that equipment installed is in accordance with the final proposal and with manufacturer’s instructions;

• System activation, also called factory startup, in which controls are programmed, calibrated and adjusted to match specifications and site conditions;

• Functional testing to confirm installed equipment operates according to the design intent and achieves stated acceptance criteria;

• Assign deficiencies to a punch list for resolution by the contractor; and

• Owner notification and acceptance of all test reports.

***Guidance on Checklist Development:*** An example of a Commissioning Checklist template can be found in Attachment 2. An editable version of the checklist can be found in the IGA tool in the worksheet entitled “Cx-Checklist”. The checklist should be developed to consist of a sampling of each type of retrofit equipment across the project (i.e. each retrofit code as utilized within the IGA tool). The sampling approach should be based on the following table:

**Table 1:** ECM Sampling Requirements for Commissioning Checklist

|  |  |  |
| --- | --- | --- |
| **ECM** | **Percentage of unit installations (per retrofit codes) to be sampled** | **Maximum sample** |
| Lighting | 10% | 10 units |
| Water | 20% | 10 units |
| HVAC Controls | 100% | None |
| HVAC Equipment | 100% | None |
| Solar PV Systems | 100% | None |

*Example 1:* If retrofit code “RELAMP\_T8\_2X28W” was utilized in 60 locations across a project, the commissioning list should be populated with sufficient installation locations to account for a quantity of 6 unit installations (i.e. 10% of the population). This quantity of 6 may be satisfied with a single installation location in a particular room/area or comprised of multiple rooms/areas if necessary.

*Example 2:* If retrofit code “RELAMP\_T8\_2X28W” was utilized in 130 locations across a project, the commissioning list should be populated with sufficient installation locations to account for a quantity of 10 unit installations (i.e. quantity 10 limit in lieu of 10% of the population). As with Example 1, this quantity of 10 may be satisfied with a single installation location in a particular room/area or comprised of multiple rooms/areas if necessary.

Equipment Verification

Utilizing the Commissioning checklist as generated by the ESCO, the installed equipment should be verified to ensure that it matches the proposed design specifications and quantities as listed on the checklist. Any variations observed should be noted in the checklist and summarized in a punch list as shown in Attachment 4 of this guide.

Equipment Functional Inspections and Testing

Utilizing the Commissioning checklist as generated by the ESCO, the installed equipment should be inspected and tested for compliance with the functional test instructions found in Attachment 3 of this guide. The items listed in the functional test instructions should be considered a standard level of performance expected of the equipment installed for the category of equipment described. Some equipment may have manufacture’s requirements that differ slightly or are not fully represented in the provided functional test instructions. The contractor’s knowledge of the equipment performance requirements, combined with specific manufacturer’s operating instructions may also be applied to the functional inspections and testing and documented in the commissioning checklist or punch lists as needed.

### 2.4 User Training and O&M Manuals

## Training

## Upon the turnover of the building’s systems to its owner at the end of the installation phase, facility personnel should also receive training on the proper operation and maintenance of the lighting and related controls and/or HVAC equipment and related control systems. This is critical because if users do not understand the controls, they may complain and attempt to override or bypass them. Likewise, where solar PV systems are installed, site personnel should have an understanding of the system’s operations, maintenance requirements and shut-down protocol in cases of emergency.

O&M Manuals

The Commissioning Process requires the contractor to submit O&M manuals and/or procedures to the owner for formal acceptance as part of project turnover. The submission is a composite document that provides detailed information about operations and maintenance of a building’s newly installed systems for the owner to use during the occupancy and operations phase of the project. In addition to warranties and manufacturer and distributor information for each control device, the submission should also detail final programming, schedules and/or calibration settings.

## 4. DOCUMENTATION OF COMMISSIONING IN POST-INSTALLATION M&V AND CX REPORT

At the conclusion of the commissioning process, commissioning observations and conclusions are to be included as a sub-section of the Post Installation M&V and Cx Report. Reporting of commissioning activities and findings will follow the general outline as provided below. A full outline of the Post Installation M&V and Cx report can be found separately in Appendix A of the FEMP ESPC ENABLE M&V Protocol.

## Outline for Commissioning Reporting

Project overview:

* Overview of commissioning scope
* General description of testing and verification methods
* General findings and summary

For each system, reporting on:

* Functional performance, with completed commissioning checklist documentation to be provided as an appendix.
* Equipment compliance with specifications
* Outstanding, non-compliance, or unresolved issues
* Operator training
* Government witnessing

# Attachment 1 - ESPC ENABLE Project Acceptance Checklist

Task Order #

Project Name

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lighting | Water | HVAC Controls | Post installation Process Step | Supporting ENABLE Document |
|  |  |  | All ECMs have been installed |  |
|  |  |  | All ECMS have been through inspection, start-up, testing, and interactive commissioning. | * Cx Checklist * Functional Test Form * Punch List |
|  |  |  | Recommended spare parts lists and spares have been provided. |  |
|  |  |  | Government witnessing of M&V activities documentation completed. | * ENABLE M&V Protocol |
|  |  |  | Appropriate training on operations and maintenance (O&M) was conducted for each ECM. |  |
|  |  |  | O&M manuals and procedures have been provided. |  |
|  |  |  | Utility rebate inspections and paperwork approved and submitted. |  |
|  |  |  | Manufacturer warranty and registration paperwork submitted. |  |
|  |  |  | All ECMs have performed properly for 30 days as of \_\_\_Enter Date\_\_\_\_. |  |
|  |  |  | Government Final Inspection, verifying that all discrepancies previously noted have been corrected. | * Punch List |
|  |  |  | Post-installation report received. (Report due by completion of 30 day ECM performance period.) | * ENABLE M&V Protocol |

All Post Installation requirements have been completed and project acceptance is confirmed as of \_\_\_\_\_Enter Date\_\_\_\_\_\_.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_

Government Technical Rep Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_

Agency Contracting Officer Date

# Attachment 2 – Example of Commissioning Checklist

Excel based commissioning checklist templates for each ECM can be found within the ENABLE IGA tool. An example of a checklist for lighting measures is as follows:

# 

# Attachment 3 – ECM Functional TEST Instructions

**The following functional test instructions are to serve as a minimum level of inspection and testing for the installed measures. For equipment or installation variations not fully represented in the following sections, the ESCO’s product expertise in combination with the manufacturer’s installation and operational instructions should be utilized to supplement the provided lists.**

|  |
| --- |
| **LIGHTING AND LIGHTING CONTROLS UPGRADES** |

**Lamps, Ballasts, Fixtures**

|  |
| --- |
| 1. Verify switch ON/OFF Function  2. Verify that all lamps illuminate  3. Fixtures shall be installed plumb and be in vertical and horizontal alignment |
| 4. Check that fixture mounting is secure  5. Ensure that any ceiling and/or wall surface affected during installation is returned to pre-retrofit condition or better. |
| 6. Ensure that all fixtures have been cleaned |
| 1. Ensure that lenses are installed properly.   NOTE: Dimmable fluorescent fixtures should be operated at full output overnight, or about 12 hours, unless the lamps are “pre-seasoned” at the factory. |

**Lighting Controls**

General Inspection.

1. Ensure that all control devices are securely attached to the wall or ceiling surface
2. Ensure that any ceiling and/or wall surface affected during installation is returned to pre-retrofit condition or better.
3. Ensure that all sensor surfaces are clean

Functional testing.Lighting control devices and control systems shall be tested, to ensure that control hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with the construction documents and manufacturer’s installation instructions. When occupancy sensors, time switches, programmable schedule controls, or photosensors are installed, at a minimum, the following procedures shall be performed:

1. ***Occupancy Sensors*:** 
   1. Certify that the sensor has been located and aimed in accordance with manufacturer recommendations
   2. For each sensor to be tested, verify the following:

* Status indicator (as applicable) operates correctly.
* The controlled lights turn off or down to the permitted level within the required time.
* For auto-on *occupancy sensors*, the lights do turn on to the permitted level when someone enters the space.
* For manual on sensors, the lights turn on only when manually activated.
* The lights are not incorrectly turned on by movement in nearby areas or by HVAC operation.

1. ***Automatic Time Switches*:** 
   1. Confirm that the automatic time switch control is programmed with appropriate weekday, weekend, and holiday (as applicable) schedules.
   2. Document for the Agency automatic time switch programming including weekday, weekend, holiday schedules as well as all set-up and preference program settings.
   3. Verify the correct time and date is properly set in the time switch.
   4. Verify that any battery back-up (as applicable) is installed and energized.
   5. Verify that the override time limit is set to no more than 2 hours.
   6. Simulate occupied condition. Verify and document the following:

* All lights can be turned on and off by their respective area control switch.
* Verify the switch only operates lighting in the enclosed space in which the switch is located.
  1. Simulate unoccupied condition. Verify and document the following:
* All non-exempt lighting turns off.
* Manual override switch allows only the lights in the enclosed space where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

1. ***Daylight Controls*:**
   1. All control devices (photocontrols) have been properly located, field-calibrated and set for appropriate set points and threshold light levels.
   2. Daylight controlled lighting loads adjust to appropriate light levels in response to available daylight.
   3. The location where calibration adjustments are made is readily accessible only to authorized personnel.

|  |
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| **WATER AND SEWER CONSERVATION** |

**Valve Toilets**

1. Ensure that new toilet is secure and does not rock

2. Ensure floor bolt caps are present and that toilet grout or caulk is present and set.

3. Check floor around base for presence of debris or old caulk.

4. Check that toilet seat is straight and tight.

5. Check for correct flush volume, using T5 Flush meter or flush into graduated container.

6. Check flush dynamics for adequate power. Flush 18 LF of toilet paper.

7. Check for leaks around top spud connection, vacuum breaker tube, handle, tailpiece and angle stop.

8. Check that supply wall plate is tight against wall and that wall tile or paint is not damaged.

**Urinals**

1. Check that the new urinal is secure and does not rock.
2. Ensure that urinal grout or caulk is present and set.
3. Check floor around base for presence of debris or old caulk.
4. Ensure that proper amount of water is delivered to fixture, by flushing into graduated container.

5. Check for leaks around top spud connection, vacuum breaker tube, handle, tailpiece and angle stop.

6. Check that supply wall plate is tight against wall and that wall tile or paint is not damaged.

**Faucet Ends**

1. Ensure that flow restrictor is present on faucet end.

2. Ensure that faucet-end-to-faucet seal is good.

3. Check for proper gallon per minute (gpm) flow rate

**Showerheads**

1. Ensure that the shower end fitting-to-supply pipe is secure.
2. Check for leaks around shower end fitting.
3. Check that all nozzles flow freely without obstruction
4. Check for proper gallon per minute (gpm) flow rate

|  |
| --- |
| **HVAC CONTROLS UPGRADES** |

**Programmable Thermostats**

1. Installed per manufacturers instructions
2. Programmed per designed control strategy
3. Verify heating operation during occupied periods
4. Verify heating operation during unoccupied periods
5. Verify cooling operation during occupied periods
6. Verify cooling operation during unoccupied periods
7. Verify system operation during occupied hours under no-load condition
8. Verify system operation during unoccupied hours under no-load condition
9. Verify system status when power is lost
10. Verify system operation when power is returned
11. Verify battery back-up (if applicable)
12. Measure room temperatures for compliance with set point.

|  |
| --- |
| **HVAC EQUIPMENT UPGRADES** |

**DX Air Cooled Condensing Units**

Installation

b. Refrigerant pipe leak tested.

c. Refrigerant pipe evacuated and charged in accordance with manufacturer's instructions.

d. Check condenser fans for proper rotation.

e. Any damage to coil fins has been repaired.

f. Manufacturer's required maintenance/ operational clearance provided.

Electrical

a. Power available to unit disconnect.

b. Power available to unit control panel.

c. Verify that power disconnect is located within sight of the unit it controls

Controls

a. Unit safety/protection devices tested.

b. Control system and interlocks installed.

c. Control system and interlocks operational.

Functional Performance Test

1. Contractor shall demonstrate operation of refrigeration system as per specifications including the following: Start building air handler to provide load for condensing unit.

Activate controls system start sequence as follows:

a. Start air handling unit. Verify control system energizes condensing unit start sequence.

b. Shut off air handling equipment to verify condensing unit de-energizes.

c. Restart air handling equipment one minute after condensing unit shut down. Verify condensing unit restart sequence.

2. Verify condensing unit amperage each phase and voltage phase to phase and phase to ground.

3. Check for unusual vibration, noise, etc.

**VAV Terminals**

Installation

a. VAV terminal in place.

b. VAV terminal ducted.

c. VAV terminal connected to controls.

d. Reheat coil connected to hot water pipe.

e. Manufacturer's required maintenance clearance provided.

Controls

a. Reheat VAV terminal controls set.

b. Reheat terminal/coil controls verified.

Testing, Adjusting, and Balancing (TAB)

a. Verify terminal maximum air flow set.

b. Verify terminal minimum air flow set.

c. TAB operation complete

Functional Performance Test

The CO will select up to 3 VAV terminals to be spot-checked during the functional performance test. Contractor shall demonstrate operation of selected VAV boxes as per specifications including the following:

a. Cooling with reheat VAV boxes:

(1) Verify VAV box response to room temperature set point adjustment.

Turn thermostat to 5 degrees F above ambient and measure maximum air flow.

Turn thermostat to 5 degrees F below ambient and measure minimum air flow.

(2) Check damper maximum/minimum flow settings.

(3) Check reheat coil operation range (full open to full closed)

**Variable Volume Air Handling Unit**

Installation

a. Vibration isolation devices installed.

b. Inspection and access doors are operable and sealed.

c. Casing undamaged.

d. Insulation undamaged.

e. Condensate drainage is unobstructed. (Visually verify drainage by pouring a cup of water into drain pan.)

f. Fan belt adjusted.

g. Manufacturer's required maintenance clearance provided.

Electrical

a. Power available to unit disconnect.

b. Power available to unit control panel.

c. Proper motor rotation verified.

d. Verify that power disconnect is located within sight of the unit it controls.

e. Power available to humidifier.

Coils

a. Chilled water piping properly connected.

b. Chilled water piping pressure tested.

c. Hot water piping properly connected.

d. Hot water piping pressure tested.

e. Air vents installed on water coils with shutoff valves as specified.

f. Any damage to coil fins has been repaired.

Heat Recovery Unit

a. Controls operable.

b. Power connected and rotation check.

c. Bypass dampers operable.

Controls

a. Control valves/actuators properly installed.

b. Control valves/actuators operable.

c. Dampers/actuators properly installed.

d. Dampers/actuators operable.

e. Verify proper location, installation and calibration of duct static pressure sensor.

f. Fan air volume controller operable.

g. Air handler controls system operational.

Testing, Adjusting, and Balancing (TAB)

a. Construction filters removed and replaced.

b. TAB report submitted.

c. TAB results within +10%/-0% of L/s cfm shown on drawings

d. TAB results for outside air intake within +10%/-0% of both the minimum and maximum L/s cfms shown on drawings.

Functional Performance Test

Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA,RA, and EA dampers from fully open to fully closed positions. Contractor shall verify operation of air handling unit as per specification including the following:

a. The following shall be verified when the supply and return fans operating mode is initiated:

(1) All dampers in normal position and fan inlet vanes modulate to maintain the required static pressure.

(2) All valves in normal position.

(3) System safeties allow start if safety conditions are met.

(4) VAV fan controller shall "soft-start" fan.

(5) Modulate all VAV boxes to minimum air flow and verify that the static pressure does not exceed the design static pressure Class shown.

b. Occupied mode of operation - economizer de-energized.

(1) Outside air damper at minimum position.

(2) Return air damper open.

(3) Relief air damper at minimum position.

(4) Chilled water control valve modulating to maintain leaving air temperature set point.

(5) Fan VAV controller receiving signal from duct static pressure sensor and modulating fan to maintain supply duct static pressure set point.

c. Occupied mode of operation - economizer energized.

(1) Outside air damper modulated to maintain mixed air temperature set point.

(2) Relief air damper modulates with outside air damper according to sequence of operation.

(3) Chilled water control valve modulating to maintain leaving air temperature set point.

(4) Hot water control valve modulating to maintain leaving air temperature set point.

(5) Fan VAV controller receiving signal from duct static pressure sensor and modulating fan to maintain supply duct static pressure set point.

d. Unoccupied mode of operation

(1) All dampers in normal position.

(2) Verify low limit space temperature is maintained as specified in sequence of operation.

e. The following shall be verified when the supply and exhaust fans off mode is initiated:

(1) All dampers in normal position.

(2) All valves in normal position.

(3) Fan de-energizes.

f. Verify the chilled water coil control valve operation by setting all VAV's to maximum and minimum cooling.

g. Verify safety shut down initiated by smoke detectors.

h. Verify safety shut down initiated by low temperature protection thermostat.

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| **Solar PV Systems** |

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| General System Level | 2008 NEC Reference | Verification & Notes |
| 1. Equipment Approval. All equipment is identified and listed for the application (includes UL 1703 listing for modules and UL 1741 listing for inverters and charge controllers). | NEC 110.2;  690.4(D);  690.60 |  |
| 2. Manufacturer’s Instructions. Equipment is installed and used in accordance with any instructions included in the listing or labeling. | 110.3(B) |  |
| 3. Site Drawings. Site drawings include descriptions and locations of major components. |  |  |
| 4. Electrical Diagram. Electrical diagram includes component interconnects, conductor types and sizes, conduit types and sizes, disconnects, and point of interconnection. |  |  |
| 5. Array Mounting Information. Mounting detail drawing includes roof type and age, mounting system, fastener spacing, and penetration weather sealing method. |  |  |
| 6. Owner’s Documentation. Documentation includes system warranty, component warranties, owner’s manuals, utility interconnection agreement, and instructions for operation and maintenance. |  |  |
| 7. AC Modules. AC modules have appropriate markings, overcurrent protection, disconnects, and ground fault protection. | 690.6;  690.52 |  |
| 8. Stand-Alone Inverter Output. Inverter output rating is equal to or greater than the largest single load on the system, but is permitted to be less than the sum of every load on the system. | 690.10(A) |  |
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| CIRCUIT VOLTAGE AND CURRENT REQUIREMENTS | 2008 NEC Reference | Verification & Notes |
| 1. Maximum System Voltage. Maximum system voltage is calculated based on module open-circuit voltage at the lowest expected ambient temperature. Module manufacturer’s temperature coefficients are used when available. | NEC 690.7(A) |  |
| 2. 600 V Limit. Maximum system voltage is less than 600 V for dwellings. Circuits over 150 V accessible only to qualified persons. | 690.7(C); 690.7(D) |  |
| 3. Maximum PV Current. The maximum PV source- and output circuit currents (used for sizing conductors and overcurrent protection devices) are based on 125% of the module short circuit current. | 690.8(A)(1); 690.8(A)(2) |  |
| 4. Inverter Current. Maximum inverter input and output circuit currents are based on inverter ratings. | 690.8(A)(3); 690.8(A)(4) |  |
| 5. Equipment Maximum Voltage. Equipment and devices are rated for maximum system voltage at lowest temperature. | 690.7; 110.4 |  |
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| CONDUCTORS AND WIRING METHODS | 2008 NEC Reference | Verification & Notes |
| 1. Conductors and Wiring Methods. Standard building-wire conductors and appropriate wiring methods are used. Conductors are rated for conditions of use. | NEC 300; 690.31(A) |  |
| 2. Conduit. PV source- and output-circuit conductors operating at more than 30 V and installed in readily accessible locations are in conduit. | 690.31(A) |  |
| 3. PV Source-Circuit Wiring. Conductors have 90°C, sunlight, and wet service resistances. Single conductor type USE-2 and specifically listed and labeled PV wire is permitted in PV source circuits. | 690.31(B) |  |
| 4. PV Conductors Alone. PV source- and output-circuit conductors are not run together with conductors of other systems. | 690.4(B) |  |
| 5. Ampacity. Conductors are sized for a de-rated ampacity of at least 125% of the maximum currents calculated or determined in 690.8(A). De-rating factors include high ambient temperatures, location on or above rooftops, and number of conductors run together within a conduit or cable. | 690.8(B); 310.15(B);  310.16 |  |
| 6. Flexible Conductors. Tracking or movable array mounts use flexible conductors identified for hard service and outdoor use. Ampacities calculated according to 400.5. | 690.31(C); 400.5 |  |
| 7. Small Conductors. Single-conductor cables in sizes 16 AWG and 18 AWG are permitted for module interconnections if they meet the ampacity requirements of 690.8. | 690.31(D); 310.15 |  |
| 8. PV Source-Circuit Conduit. Where DC PV source circuits are run inside a building, they are in metal conduit from the point of penetration into the building to first accessible disconnect. | 690.31(E) |  |
| 9. Connectors. Connectors are polarized, non-interchangeable, guarded, latching or locking, have “first-to-make/last-to-break” contact for grounded conductor, and either are rated for interrupting current or require a tool to open. | 690.33 |  |
| 10. Wiring Connectors. Connectors are listed for the intended use and environment. Screw terminals are tightened to recommended torque. Crimp-on terminals are used with appropriate crimping tool. | 110.14 |  |
| 11. Junction Boxes. Junction boxes are of appropriate type and size and allow the conductors within to be accessible. | 690.34; 314 |  |
| 12. Color Codes. Grounded conductors are marked white or gray and grounding conductors shall be green, green/yellow, or bare. | 310.12 |  |
| 13. Strain Relief. Strain relief or conduit is used with all conductors. | 300.4 |  |
| 14. Multi-wire Branch Circuits. No multi-wire branch circuits are allowed on stand-alone 120 V inverter output circuit or panels. | 690.10(C) |  |
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| OVERCURRENT PROTECTION | 2008 NEC Reference | Verification & Notes |
| 1. Protected Circuits. PV source circuit, PV output circuit, inverter output circuit, and battery circuit conductors and equipment are protected in accordance with Article 240. | NEC 690.9(A); 240 |  |
| 2. Multiple Power Sources. Circuits connected to multiple power sources are provided overcurrent protection from each source. | 690.9(A) |  |
| 3. Ratings. Overcurrent protection devices are rated for not less than 125% of the maximum currents calculated or determined in 690.8(A). | 690.8(B); 240.4; |  |
| 4. Transformers. Overcurrent protection is provided for power transformers in accordance with Section 450.3. | 690.9(B); 450.3 |  |
| 5. Supplementary Overcurrent Protection. Branch-circuit or supplementary-type overcurrent protection devices are permitted on PV source circuits. | 690.9(C) |  |
| 6. Listed for DC. Overcurrent protection devices in DC circuits are listed for such use and have the appropriate voltage, current, and interrupt ratings. | 690.9(D) |  |
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| DISCONNECTS | 2008 NEC Reference | Verification & Notes |
| 1. Array Disconnect. A disconnect is provided between the PV power system output and other building conductors. | NEC 690.13 |  |
| 2. Accessibility. Array disconnect is installed at a readily accessible location either on the outside of the building or structure or inside nearest the point of entrance of the system conductors. | 690.14(C)(1);  690.31(E) |  |
| 3. Marking. Each PV system disconnect is marked as such, and suitable for the intended use. | 690.14(C)(2);  690.14(C)(3) |  |
| 4. Grouping. There are no more than six disconnects for each source of power. Disconnects for each power source are grouped together. | 690.14(C)(4);  690.14(C)(5) |  |
| 5. Equipment Disconnects. Disconnects are provided to disconnect equipment (inverters, batteries, charge controllers, etc.) from all ungrounded conductors of all power sources. | 690.15 |  |
| 6. Fuses. Disconnects are provided to independently disconnect a fuse from all sources of power if the fuse is energized from both directions. | 690.16 |  |
| 7. Features. Disconnects open all ungrounded conductors, are readily accessible, externally operated, have ON/OFF indication, and have appropriate interrupt rating. Manually operated switches and circuit breakers may fulfill these requirements. | 690.17 |  |
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| GROUNDING | 2008 NEC Reference | Verification & Notes |
| 1. Ungrounded Systems. Ungrounded systems include disconnects, overcurrent protection, and ground-fault protection. Equipment is listed for use with ungrounded systems. | 690.35 |  |
| 2. Module Grounding Continuity. Module connections are such that removal of a module does not interrupt a grounded conductor to another PV source circuit. | 690.4(C) |  |
| 3. Ground-Fault Protection. Ground fault protection is provided for grounded arrays. | 690.5 |  |
| 4. PV System Grounding. One DC conductor is grounded for two-wire PV systems operating above 50 V. | 690.41; 250.4(A) |  |
| 5. Single-Point. DC grounding is made at a single point on the PV output circuit. | 690.42 |  |
| 6. Equipment Grounding. Non-current-carrying metal components are grounded, including module frames, mounting structures, equipment, conduit, and boxes. | 690.43 |  |
| 7. Equipment Grounding Conductors. Equipment grounding conductors are routed with PV circuit conductors. | 690.43 |  |
| 8. Equipment Grounding Conductor Size. If array has GFP, the equipment grounding conductor is sized according to 250.122. If array does not have GFP, the equipment grounding conductor is sized for at least twice the de-rated circuit conductor ampacity. | 690.45; 250.122 |  |
| 9. Grounding Electrode Systems. The AC system is grounded according to 250.50 through 250.60. The DC system is grounded according to 250.166 or 250.169. | 690.47(A); 690.47(B); 250 |  |
| 10. Common Grounding. If system includes both AC and DC systems, the grounding electrode systems are bonded together. The bonding conductor is sized for the larger of the  AC and DC requirements. Separate DC and AC grounding electrodes are permitted, or both grounding systems may use the premises AC grounding electrode. The grounding electrode conductor is sized to meet both AC and DC grounding requirements. | 690.47(C); 250 |  |
| 11. Array Grounding. Array is grounded with separate grounding electrode system, unless it would be within 6’ of premises electrode. | 690.47(D) |  |
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| MARKINGS AND LABELS | 2008 NEC Reference | Verification & Notes |
| 1. Array Ground-Fault Protection. Interactive inverter, groundfault indicator, and/or battery bank label warns of shock hazard during ground fault. | 690.5(C) |  |
| 2. Modules. PV modules are labeled with open-circuit voltage, operating (maximum power) voltage, maximum permissible voltage, operating (maximum power) current, short-circuit current, and maximum power. | 690.51 |  |
| 3. System Info at DC Disconnect. PV power source is labeled with maximum power current, maximum power voltage, maximum system voltage, short-circuit current, and maximum rated output current of charge controller (if installed) at the DC disconnect. | 690.53 |  |
| 4. Inverter Info at AC Disconnect. Point of interconnection is labeled with inverter operating AC voltage and rated AC output current at the AC disconnect. | 690.54 |  |
| 5. Batteries. Battery bank is labeled with maximum operating voltage, equalization voltage, and polarity. | 690.55 |  |
| 6. Stand-Alone Systems. Exterior visible notice indicates the structure contains a stand-alone system and identifies the locations of disconnects. | 690.56(A) |  |
| 7. Interactive Systems. Exterior visible notice indicates identifies the locations of array disconnect and utility service disconnect, if not located together. | 690.56(B) |  |
| 8. Single 120 V Supplies. A stand-alone system supplied by a 120 V inverter includes a label warning against connecting multiwire branch circuits. | 690.10(C) |  |
| 9. Ungrounded Systems. Ungrounded systems include a label warning of a shock hazard. | 690.35(F) |  |
| 10. Disconnect Energized While Open. If all terminals of a disconnect are energized when open, a label warns as such. | 690.17 |  |
| 11. Marking. Panels containing overcurrent protection devices supplying power to busbar are marked to indicate all sources of supply. | 690.64(B)(4) |  |
| 12. Back-Fed Breakers. Back-fed circuit breakers for load-side connections are labeled as inverter output connections with a warning not to relocate. | 690.64(B)(7) |  |
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| CONNECTION TO OTHER SOURCES | 2008 NEC Reference | Verification & Notes |
| 1. Inverters UL Listed. Inverter is listed and identified for interactive operation. | 690.60, UL1741 |  |
| 2. Islanding. Interactive inverters will de-energize if utility power is lost. Bimodal inverters may continue to operate if disconnected from utility power. | 690.61 |  |
| 3. Neutral Loading. If two-wire inverter is connected to system with multiple ungrounded conductors, sum of load and inverter’s current rating does not exceed ampacity of grounded conductor. | 690.62 |  |
| 4. Unbalanced Interconnections. Loads are balanced on three-phase systems with interconnected single-phase inverters. Three-phase inverter automatically de-energizes if system becomes unbalanced. | 690.63 |  |
| 5. Point of Connection. The output of interactive inverter is connected to either the supply side or the load side of the utility service disconnect. | 690.64 |  |
| 6. Load-Side Connection. If load-side connection, the inverter output connection is made at dedicated circuit breaker or fusible disconnect. | 690.64(B)(1) |  |
| 7. 120% of Busbar Rating. Sum of ampere ratings of all breakers supplying power to panel does not exceed 120% of the busbar rating. | 690.64(B)(2) |  |
| 8. GFCI. Interconnection is on the line side of all ground-fault protection equipment. | 690.64(B)(3) |  |
| 9. Suitable for Backfeed. Circuit breakers used for load-side connections are suitable for such operation. | 690.64(B)(5) |  |
| 10. Back-Fed Breakers. Back-fed circuit breakers for load-side connections are positioned at the opposite end of the panel as the utility service disconnect. | 690.64(B)(7) |  |

# Attachment 4 – Punch List

**ECM-X: *Add ECM title here***

(This punch list may be used to when there are minor activities to be completed that the agency does not wish to halt the commissioning process for. These activities are to be assigned to the contractor and completed by the specified date.)

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| --- | --- | --- | --- | --- | --- |
| Item # | Measure ID | Building ID | Area Description | Description of work to be completed | Date Completed |
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**Accepted By:**

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Government Representative/Title Date