PHOTOVOLTAIC PROJECT DEVELOPMENT AND COMMISSIONING

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ABSTRACT

As the United States continues to increase its implementation of PV technology, the safety, quality and reliability of these systems becomes increasingly important, both to the industry and the public at large. One way to improve the likelihood of successful PV projects is to incorporate thorough commissioning (Cx) processes into the specification, design and construction aspects of project development, as well as throughout the lifespan of the system. While some project developers do offer commissioning services, this paper will argue that hiring an independent (i.e. "third-party") commissioning agent is the best way for the system owner to maximize the likelihood that the project will be safe, reliable, productive, and meet any other goals specific to the project and the owner's needs.

1. INTRODUCTION

Photovoltaic (PV) systems are growing in number and in size in the United States[i]. Homeowners, business owners and utilities are increasingly choosing to install PV systems and, for a number of reasons such as growing equipment efficiencies and decreasing materials costs, the rated power those systems produce is on the rise. It is crucial to the long-term success of the PV industry that the safety, quality and reliability of these systems is unimpeachable, and, unfortunately, the current system of quality control does not go far enough to make that a reality. The best way to maximize the likelihood of designing, constructing and maintaining a successful PV system is to incorporate the services of an independent commissioning agent whose primary focus is to protect the interests of the system owner (i.e. "customer").

The term "commissioning" comes from shipbuilding, where a commissioned ship is one that has been thoroughly inspected, all of the on-board systems have been tested, and the prospective crew has been extensively trained[ii]. In project engineering, the term commissioning means largely the same thing, though the items being inspected and the systems being tested can vary greatly. Whether in shipbuilding or PV system construction, the goal of the commissioning process is to ensure that all aspects of the final product – from the smallest component to the most complex system – meet the owner's intended operational requirements.[iii]

This paper will also utilize to the term "quality." Quality in this context refers to anything that pertains to the success of the project in meeting the goals of the system owner. This can include code compliance, achieving energy production estimates, minimizing operations and maintenance (O&M) costs, achieving the estimated Levelized Cost of Energy (LCOE), proper equipment selection, or any other factor the system owner deems relevant to project success.

The Cx process can be a valuable part of any PV system, but it is particularly important to commercial- and utility-scale systems where structural loads are greater, electrical hazards are more dangerous, and monetary investments are higher. This paper will focus on these larger-scale project processes,

but the fundamental ideas are also applicable to residential installations.

2. THE CURRENT SITUATION

In the United States today, many PV systems are coming on-line without undergoing a rigorous Cx process. Project quality assurance is often left up to the developer, as the customer does not generally have the knowledge of PV technology and installation best practices to adequately assess system quality. The customer may feel that the inspection conducted by the Authority Having Jurisdiction (AHJ) serves to confirm system quality, but AHJ inspectors are only tasked with ensuring that the system is compliant with all applicable codes appropriate to their specific jurisdiction; they do not inspect for installation best practices, performance-related issues, potential O&M cost issues, or any other project-specific items that do not relate directly to legally enforceable code requirements.

The customer may also rely on the project developer's internal Quality Assurance / Quality Control (QA/QC) processes to protect their interests in terms of meeting quality goals for the PV system. While many developers (particularly in the commercial and utility markets) do have robust QA/QC programs, these programs are intended by design to minimize overall project cost to the developer, not to ensure that the customer gets the highest quality PV system possible. Even in the case where the developer may be financing the project internally, there can be conflicts that arise between the best interests of the customer and those of the developer.

In situations where large projects are being financed by a third party (e.g. a bank or investment group), the financing entity is increasingly looking to independent Cx agents to provide assurance of overall system quality. One of the primary barriers to entry into the PV investment market is uncertainty, particularly uncertainty in the long-term cost of designing, constructing and maintaining a PV system. Investors see an independent Cx agent who is hired specifically to represent their interests as a means to mitigate risk due to uncertainty.

The Federal Government is also utilizing independent Cx agents during the development of renewable energy projects. The Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) states the following in its "Guide to Integrating Renewable Energy in Federal Construction":

"An independent, third-party commissioning agent brings the most objective perspective to the commissioning process. Appointing a member of the project design team or contractor can create a conflict of interest, as these parties will be tasked with reviewing, testing, and identifying deficiencies in their own work."[iv]

A unique challenge created by PV installations on federal government properties stems from the fact that such installations often do not require traditional permitting processes. Although this can save time and cost associated with PV installation, it also leaves federal facilities managers, energy managers, and construction superintendents responsible for ensuring the PV contractor designs and builds in a safe and code-compliant manner.

While these federal employees are usually experienced in general and electrical construction, they are not always familiar with PV system construction or the factors that can impact the success of a PV project. Building owners and facilities managers face uncertainties regarding whether their PV system meets current safety codes and standards, and is installed using best practices that help ensure the system performs as expected at start-up and throughout the project lifecycle. To address these concerns, federal PV system owners are increasingly engaging independent Cx agents to assist with PV project development.

3. THE IMPORTANCE OF COMMISSIONING

The term "commissioning" can mean different things to different people, especially in the world of PV systems. For some, the Cx process is simply an operational check-out inspection of a completed system aimed at affirming that the system is built according to the approved design documentation and is performing as expected. On the other end of the spectrum is a "cradle to grave" lifecycle Cx process that begins at project inception and ends when the project reaches the end of its useful life. Lifecycle Cx is a systems-oriented approach that acknowledges and appreciates how interconnected the different facets of a project are and emphasizes the need for communication and quality assurance throughout the entirety of the project. Lifecycle commissioning by a qualified Cx team is the best way to maximize the likelihood that a PV project will be designed, constructed and operated in a manner that meets the system owner's project requirements and adheres to all applicable codes, standards and laws.

As with most construction projects, PV projects are often built by developers whose primary concern is the opportunity to make a profit. While there are many highly reputable and competent PV system developers in the industry, it is inevitable that there are some that do not have a track record of successful completion of high quality projects. The industry's astounding growth rate means that many new players entering the space do not have extensive

experience in PV project development. The independent Cx agent's role is to help the customer identify a quality project developer and then represent the customer's interests in an informed manner throughout the project lifecycle.

4. THE LIFECYCLE COMMISSIONING PROCESS

The Lifecycle Cx process begins in the pre-design phase when the PV system owner (or potential system owner) is considering variables such as:

- Where to locate the system equipment
- What contractor to hire for system construction
- How much energy production should be expected
- What financing options are available
- What lifecycle / O&M costs should be expected
- What aesthetic considerations are relevant

The independent Cx agent brings unbiased, experience-based knowledge to help the customer make the initial decisions that align with specific project goals. (Note that the term "Cx agent" can refer to an individual performing specific Cx duties, or to a company hired to execute the Cx process.)

After the pre-design phase, the independent Cx agent is involved with all major design decisions for the project. They should work closely with the site surveyor, project engineer, procurement manager, construction superintendent, and anyone else who plays a significant role in the success of the project. Throughout the design, procurement and construction process the independent Cx agent facilitates communication among the developer, the sub-contractors, the customer, the AHJ, and the interconnecting utility, and does so with only the best interests of the customer in mind. Examples of situations in which the Cx agent should play a role include:

- Equipment selection: Balancing the materials cost with quality based on manufacturer track record and established performance in the field.
- Energy production estimates: Depending on the project financing vehicle, a developer may be incentivized to overestimate energy harvests. The Cx agent should be well-versed in production estimating tools and be able to provide a realistic analysis based on site conditions and selected equipment.
- AHJ negotiations: It is not uncommon for the AHJ to have concerns about certain specific aspects of a proposed project based on zoning ordinances and jurisdictional codes. The independent Cx agent can provide objective expertise and conflict resolution.
- Design considerations: Solar PV is a rapidly developing industry and relevant codes, standards, technologies and best practices are constantly evolving. An independent Cx agent can help the customer and developer navigate this changing landscape to design and construct the optimal PV system for the application.
- Review and approve all project documentation: Large-scale projects will have extensive documentation that could include feasibility studies, multiple plansets, permit and interconnection applications, O&M manuals, architectural reviews, etc. The Cx agent should review all system documentation for consistency with the customer's project goals.
- In-field construction considerations: Adjustments occasionally need to be made in the field to account for unforeseen circumstances or inaccuracies in the approved planset, and decisions often need to be made rapidly to prevent construction delays. The Cx agent can assist with these considerations and prevent the customer from feeling unnecessarily pressured.

After the construction process is completed, the installation contractor should finalize the internal QA/QC process to ensure the system meets their own standard of quality and to prepare for subsequent inspections (e.g. county inspection, city inspection, fire marshal inspection, Cx inspection). Once the installer is satisfied with the final product, applicable AHJ inspections must be completed. The independent Cx agent should be present at the AHJ inspection to document the inspection and assist with questions or concerns the AHJ inspector may have. It is worth noting that AHJ inspectors may not have much experience with PV, especially in geographic markets that do not have a large installed PV capacity. PV systems are subject to certain specific code sections that are not often encountered on other electrical installations (e.g. National Electric Code articles 690 and 705[v]). Inspectors who are not familiar with these specific codes and other applicable requirements can miss crucial safety violations.

After the system passes all applicable AHJ inspections, the Cx inspection process can begin. The Cx inspection should happen after all other inspections have been completed, because it is not uncommon for inspections to result in punch lists that require additional work on the PV system. The Cx inspection should include a physical and visual inspection of all aspects of the PV system, as well as a measurement and verification (M&V) process that involves extensive testing of the system's physical and electrical properties.

Fig. 1. Physical Inspection: During the Cx inspection, the Cx agent should be physically touching modules, enclosures, raceways, etc. to ensure these elements are securely fastened in place.

Tasks that all Cx inspections should cover include[vi]:

- Verification of installation completion
- Verification of installation safety
- Verification of system aesthetics
- Verification that equipment and materials are suitable for the application
- Documentation of as-built conditions
- Verification of proper system operation
- M&V of system performance

M&V of system performance is a crucial part of the Cx process. The details of this process are well documented by Blake Gleason in the October/November 2009 issue of SolarPro Magazine. The basic steps of the process include:

- Record multiple measurements of the instantaneous inverter output, plane-of-array irradiance, and cell temperature for every inverter.
- Calculate the appropriate system de-rate factors.
- Calculate the expected system performance.
- Compare the expected system performance with the inverter output measurements.

There are an increasing number of tools on the market that are designed to assist in the M&V process specific to PV systems (manufacturers include Daystar, Solmetric, Seward Solar and Tritec). While these tools can save time, produce visually impressive graphs, and provide value-added functions such as insulation resistance testing, the Cx agent should understand the calculations and processes that allow proper system operation to be verified. Regardless of the method used to obtain them, initial performance measurements form the baseline performance of the PV system which can then be referenced throughout the system lifetime.

Most PV systems currently being installed incorporate monitoring, and those that don't, should. Monitoring systems can be extremely valuable in accurately measuring long-term system performance as well as identifying and diagnosing O&M issues. Verification and testing of monitoring systems is a vital component of verifying proper system operation during the Cx inspection.

Every Cx agent will have their own process for executing the Cx inspection process, but certain elements should always be present including:

- A Cx checklist: the checklist can be analog or digital, but it should include a means to record all relevant details for every aspect of the PV system.
- A camera: Extensive photo documentation should be gathered for the system in general, with particular attention to issues or irregularities that are discovered.
- Personal Protection Equipment (PPE): The Cx agent should be fully compliant with all applicable Occupational Safety and Health Administration (OSHA) standards, including any specific to the system location or application.
- Measurement devices for irradiance and cell temperature: Irradiance and cell temp readings are vital to verifying system performance. Measurement devices should be accurate, durable, and properly calibrated.
- Insulation resistance tester: Sometimes called a mega-ohm-meter or megger, this tool ensures that conductor insulation has not been compromised.
- AC/DC Multimeter: All voltages in the system (e.g. string, homerun, and inverter output) should be verified.

The Cx inspection process can last anywhere from a few hours to a few weeks, depending on the size and complexity of the PV system and the size of the Cx inspection team. Prolonged periods of cloudy or inclement weather can also affect inspection times.

After the Cx inspection is complete a Cx report is generated. The report can take many forms, but should include:

- A system overview containing all of the fundamental system details (e.g. number, type and size of inverters and modules, array orientation(s), type of mounting system(s), interconnection type, etc.)
- Relevant excerpts from the planset showing the key system components and layouts.
- A detailed list of the physical inspection findings with photo documentation and references to applicable codes and standards. This list may include recommended corrective actions and can also serve as a final punchlist for the installation contractor.
- A detailed analysis of system performance showing expected vs. actual measurements and de-rate values and assumptions.
- An Analysis of Findings summarizing the Cx inspection outcomes and recommended next steps.

Once the installation contractor has remedied all outstanding issues to the satisfaction of the Cx agent (either through photo documentation or a follow-up punchlist inspection), the system can be approved for operation via a letter, certificate, or other means agreed upon by the Cx agent and system owner.

Once the PV system has been approved for operation, the ongoing Cx process begins. This process includes performing all scheduled maintenance according to equipment manufacturers' requirements, system inspections at regular intervals to identify existing and developing O&M issues, and ongoing evaluation of system performance as compared to the baseline established by the initial system performance measurements. Note that most PV modules on the market today come with production guarantees, and the only way to ensure those guarantees are verified and enforced is to closely monitor system output. All activities in the ongoing Cx process should be documented and archived, as this data can be invaluable if unexpected issues do arise.

All personnel that come into contact with the PV system should be properly trained on the operational and safety factors relevant to their roles. This function is often performed by the developer or installation contractor, but it is a good idea to have a member of the Cx team present as well. It is possible for differences of opinion to arise surrounding the correct O&M and safety procedures and it is best to work those out as early in the process as possible. The system owner may alternatively choose to have the Cx agent perform the training themselves, based on the agent's skills and familiarity with the specific system components and equipment manufacturers.

The final stage in the Cx process is system de-commissioning. There is not a lot of precedent for this aspect of system commissioning because PV technology is relatively young and lasts a relatively long time. As such, most systems that have been constructed globally are still in operation. However, all systems will eventually come to the end of their service lifetime and, at that point, it will be important that they are disassembled by qualified personnel and all equipment is repurposed, recycled or disposed of appropriately and efficiently. Considerations for PV system de-commissioning include:

- Is the system safe to touch? Many years of exposure to the elements can be brutal on electrical and structural systems. A qualified person should inspect the system for potential safety issues before de-commissioning.
- Can the modules be re-purposed? Answering this question will require a detailed look at their power output and physical condition.
- Can other system components be re-purposed? Depending on the quality of the materials used and the environmental conditions at the system location, there may be significant value available on the used equipment market.

5. CONCLUSION

Engaging a Cx agent early in a PV installation process provides better opportunity to ensure a safe and high-performing PV system without additional overhaul or maintenance costs. However, bringing the third-party expertise of a Cx agent into the process at any time can help mitigate long-term performance, safety and O&M issues. However one chooses to specify, design, construct and operate a PV system, care should be taken to ensure that knowledgeable people are doing quality work at every step in the process. Involving a reputable independent Cx agent is one way to increase the chances of that happening.

8. ACKNOWLEDGEMENTS

SRA would like to acknowledge the following parties for their contributions to PV system Cx:

The International Electrotechnical Commission (IEC), SolarPro Magazine, the US Department of Energy, the North American Board of Certified Energy Practitioners (NABCEP), The International Association of Electrical

Inspectors (IAEI), Underwrites Laboratory (UL), and Solar Energy International (SEI)

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