

DESIGN REVIEW AND APPROVAL OF GRID-TIED PHOTOVOLTAIC SYSTEMS

Brian N. Farhi*, James P. Dunlop, PE,
Jerry Ventre, Ph. D., PE, Gobind Atmaram, Ph. D., PE, Kevin W. Lynn
Florida Solar Energy Center
Photovoltaics & Distributed Generation Division
1679 Clearlake Road
Cocoa, Florida 32922-5703
bfarhi@fsec.ufc.edu

ABSTRACT

The Florida Solar Energy Center has been accredited by both the American Association for Laboratory Accreditation and PowerMark Corporation to certify grid-tied photovoltaic systems. The certification process involves both the testing of photovoltaic modules for performance ratings and the review and approval of system designs to provide photovoltaic system design certification. This paper focuses on the design review and approval process, which consists of a documentation review and focuses on the completeness and accuracy of instructions, schematics, and accompanying materials. System designers have received substantive critiques and assistance through the third-party technical reviews used in this process. As a result, photovoltaic system manuals that accompany reviewed systems lead to a greater likelihood of code-compliant and high-performing installations.

INTRODUCTION

In recent years, increased subsidies, advancements in equipment and technology, and reductions in price have resulted in a growing market for grid-connected PV systems. Although performance, reliability and safety are areas of serious concern in all PV systems, they are especially important for grid-tied systems because problems encountered may affect the reliability of the utility network and other customers. Also, unacceptably high rates of system difficulties and failures negatively impact grid-tied photovoltaic markets. Two of the leading causes of photovoltaic system failures, poor design and poor installation, could be largely avoided when the appropriate design review measures are implemented. The design review process discussed below provides a method for evaluating system designs. The goal of the evaluation is to preemptively isolate potential problems such as poor design, code infractions, ambiguous instructions, and lack of sufficient information and documentation that the customer may need over the lifetime of the system.

RELEVANCE

The design review and approval process is beneficial to manufacturers, installers, end users, and code officials. It provides manufacturers, system integrators, and suppliers with

third-party input on their designs and encourages the adoption of complete schematics and explicit details to reduce installation errors. The design review process also provides documentation that is extremely useful to code officials and increases their confidence level when inspecting installed systems. Although code officials are tasked with the responsibility of ensuring that PV systems are installed safely and properly, the lack of technology-specific understanding sometimes leads to incomplete or inaccurate assessments. Most importantly, customers need electrical schematics, parts lists and component specifications when systems require service and repair over the system lifetime.

To help ensure that these systems are properly designed, the Florida Solar Energy Center (FSEC) has worked with leading experts in the PV field to develop criteria for evaluating designs based on relevant codes, standards and accepted practices [1, 2]. The goal of these measures is to help ensure the safety and quality of installed PV systems, and provide quality assurance to installers, consumers and financiers.

Design review is a topic familiar to the Florida Solar Energy Center (FSEC): it has reviewed and certified solar water heating equipment since 1976, and has over twenty years experience with photovoltaic system design. The PV design review process was initiated by FSEC in 1999 through the *Florida PV Buildings Program* in collaboration with Sandia National Laboratories and the Florida Department of Community Affairs. In 2001, FSEC received two important accreditations pertinent to the certification of grid-tied PV systems. The first, awarded by American Association for Laboratory Accreditation (A2LA), recognizes FSEC for following the quality systems requirements of ISO/IEC 17025 – *General Requirements for the Competence of Testing and Calibration Laboratories*. The second, awarded by PowerMark Corporation, recognizes FSEC specifically for following procedures outlined in PowerMark document PV 3.3: *Design and Documentation Review and Evaluation Requirements for Grid-tied Residential and Small Commercial PV Systems*, as a component of the PowerMark Photovoltaic Certification and Labeling Program [3]. PowerMark is the lone U.S. administrator for the Global Approval Program for PV (PV-

GAP) and the only U.S. PV testing and certification program that meets the requirements for international reciprocity.

DESIGN REVIEW REQUIREMENTS

Designs are reviewed for evidence of code/standard compliance and appropriate industry practice. The designs are documented by a comprehensive System *Manual* that meets the minimum requirements outlined in PowerMark-approved documentation. Though it is not possible to guarantee NEC or other code-compliance based strictly on documentation, the review process identifies and eliminates potential system design problems for suppliers. It also provides assurance to code officials that the approved designs have been through a rigorous engineering and documentation review and, if properly installed, should be code compliant.

Criteria for system approvals are based on applicable codes and standards, and consistency with industry-accepted design practices. Evidence to support these criteria must be contained in the supplier's *System Manual*. General criteria include: 2002 National Electrical Code conformance in defined aspects of design, evidence of applicable product listings, evidence of PV module qualification tests, conformance of overall system design and installation requirements with IEEE Standard 929, and warranty information for complete system and individual components, among other requirements [4, 5, 6].

The process used to obtain system approval is straightforward. The system manufacturer, designer, or distributor typically begins the process by submitting an application form with their complete design package to FSEC's PV Design Review Committee. Materials such as a design template and a copy of the checklist used for design evaluation are posted on the FSEC website to assist designers in identifying the key elements that will be examined and the methods used for the analysis [7, 8].

Once the initial package is received, it is reviewed using FSEC criteria and PowerMark guidelines. This involves four main areas of evaluation: system documentation, electrical design, mechanical design, and component documentation. The Design Review Committee Chairperson conducts a preliminary review of these materials prior to meeting with the entire Design Review Committee (DRC). If the DRC's analysis shows deficiencies in the design package, the applicant is contacted with a list of what is required. The applicant then responds and the issue is brought back to the full DRC unless the changes are clearly sufficient. Once the review has been successfully completed, the applicant is notified and the design is listed on the FSEC website. The initial design review typically requires 30 days, assuming all materials are included in the design package and all criteria are met. If not, the review process may take longer. At present, there is no charge for the design review, though this policy may change in the future.

System Documentation

The first part of the design review focuses on the comprehensiveness of system documentation. The following items are required: system description, supplied parts list, list of

additional required parts, installation and start-up procedures, operation procedures, safety information, warranty, electrical schematics, mechanical design plans, and component specification sheets/manuals. The information provided must be sufficient to meet the required criteria. For example, the warranty statement could be as extensive as several pages, detailing the specific cases in which the warranty does or does not apply, or the warrant could be three sentences referring to the warranty period and general terms.

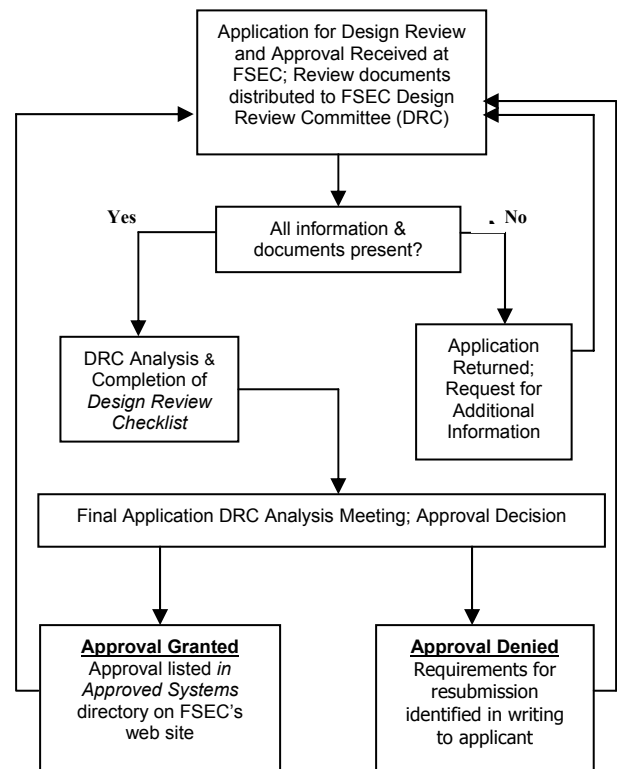


Figure 1: Flow Chart of Design Review & Approval Process

Electrical Design

The most extensive and rigorous analyses take place in the Electrical Design portion of the review. In this section calculations are verified, schematics evaluated for comprehensiveness, and detail of instructions examined. Specifically, each aspect of the electrical design is reviewed using the latest version of the National Electrical Code (NEC), with other codes and standards such as ASHRAE 90.1 playing a lesser role. It must be reiterated that this review process does not ensure code compliance, but assists applicants in resolving potential code-related issues. Like other codes, electrical codes are often open to interpretation. Most of the electrical review process involves fundamental and unambiguous rules; however, when interpretation is required, the DRC collectively agrees upon the most appropriate translation [9].

Wire type, gauge, and potential substitutes are mostly verified using tables and calculations found in Articles 310 and 690 of the NEC. Similar sizing and rating requirements are calculated for disconnects, over-current protection, junction boxes, service panel connections, and grounding. Some aspects of the electrical design, such as conduit size and type, are often determined in the field. To avoid the burden of specifying each acceptable kind and size for certain components, it is acceptable for designers to state the criteria that must be met by the given component (e.g., “see NEC Articles 342-362 for appropriate conduit selection”). Junction boxes, conduit, and conduit/junction box fittings are among the components that can be more generally specified. Wiring, fuse, and disconnect selection are some of the components that require more explicit detail not only because of their significance to safety and reliability, but because of their effects on performance as well.

Mechanical Design

The primary goal of the mechanical design section is to make sure the array mounting assembly is structurally sound. Typically, manufacturers submit a letter with a professional engineer’s seal to certify that the structural support will withstand given loads. In some rare occasions, a test report from a third-party source will be submitted in place of the professional engineer’s seal to meet this criterion.

Similar to the electrical design, the mechanical design is to be accompanied by the appropriate drawings and instructions. The critical components, such as lag bolts, brackets, etc., must be specified, since they are integral to the PE-approved mechanical design. The particular type of weather sealant need not be specified, although applicants are strongly encouraged to give an appropriate list of sealant types when possible.

Component Specification Sheets/Manuals

Each of the major system components must be accompanied by the manufacturers’ specifications sheets, installation/operation manuals, and other details relevant to the component’s function. Component information is required for PV modules, inverters and, when applicable, charge controllers and batteries.

Voltage, current and power limits and operating points are key parameter sets reviewed. To maintain system safety and code compliance, Underwriters Laboratories (UL) listing is required for components as well: UL 1703 for modules, UL 1741 for inverters. Institute of Electrical and Electronics Engineers (IEEE) compliance is also required for inverters and modules. Interconnection standard IEEE 929 is necessary for inverters, while IEEE 1262 (or equivalent International Electrotechnical Commission standards) compliance maintains a high level of quality through module qualification testing. Additionally, PV modules must have third-party rating verification to ensure power output within 10% of their nameplate rating. These tests may be conducted by Arizona State University, Sandia National Laboratories, the National Renewable Energy Laboratory, FSEC, or other qualified institutions.

For battery-based systems, relevant battery and charge control specifications are required. Factors such as battery type, capacity (and associated charge rate), charge control setpoints, series/parallel configuration, and recommended storage location must be outlined. Evidence of UL listing for charge control devices is also required.

TECHNICAL BENEFITS

The design review process has had a positive impact on nearly every design that has been reviewed. In some cases the improvements are a result of the designers compiling all of the relevant information into one resource. In many others, technical changes are made. For example, one design’s electrical schematics indicated that the wiring configuration should be installed in a manner that would circumvent the battery system. Once the designer realized their oversight, they amended their designs. In another case, a designer submitted a design that would supercede NEC voltage specifications if the temperature conditions were not appropriately qualified. After the designer was made aware of this, their company added information that would help prevent the installation of the otherwise well-designed system in a non-compliant manner.

These types of changes also have implications on performance and reliability. Performance problems can result from improper wire or component sizing. For instance, if an inverter is over-sized for an application, it may not operate as efficiently as desired. For that matter, it may not turn on at all if the minimum system voltage and current are never achieved. The system may be fully code-compliant in all other respects, but that does not imply it operates well.

With regard to reliability, there are numerous cases where poor workmanship leads to system failure. By spelling out the critical details of the installation and referencing the appropriate guidelines, manufacturers and system designers can be confident that they have provided installers with all the information required to avoid installation errors (beyond the locality’s licensing or certification requirements).

Likewise, this level of detail may expedite the installation process. Although it may be common for experienced installers to skim these manuals, the manual will often be the first place installers seek answers when questions arise. The documentation becomes especially important when the system requires service, repair or replacement – often by someone other than the original installer.

MARKETING/PROGRAMMATIC BENEFITS

Several manufacturers have become interested in the design review process for reasons other than third-party system analysis. The marketing angle has also been explored by many applicants. By stating their system has been approved through this process, retailers can help distinguish their products over their competitors’. Because there has not been much publicity regarding the review process, it is not something most consumers currently seek. However, in the future it is expected that approval through this process will be seen as an effective product assurance measure. While not guaranteeing the system

is code compliant or works well, it does assure that specific criteria have been met, thereby increasing the probability that code-compliance, performance and reliability are consistent with design objectives.

Within the State of Florida, all grid-connected PV system designs installed under the *PV Buildings Program* have undergone the design review process to qualify for rebate funds. These approvals have been an important part of quality PV installations within Florida. With other states and programs seeking to implement quality assurance measures for PV system designs, the design review process has been gaining greater exposure and relevance. States in the Northeast and Pacific Northwest are considering the adoption of such system approvals as a requirement within their rebate programs.

There has also been discussion of creating a set of national guidelines through the US Department of Agriculture, the Government Services Agency and/or the Federal Energy Management Program to provide easier access for states, agencies, and programs to adopt these quality standards. The technical design review assistance offered by FSEC has already helped to improve the quality of designs and design documentation. However, a national listing of such approvals could be of even greater benefit to industry, end users, and code officials.

CONCLUSIONS

Overall, the Design Review process has been successful in achieving its primary goal: improving the quality of photovoltaic system designs and documentation. The number of systems reviewed markedly increased throughout 2002 and this trend is expected to continue as FSEC takes a more proactive approach to soliciting system designs. A number of states and territories will be using the design approval process for rebate eligibility requirements, which is expected to also add to the number of systems reviewed. As a result, a number of design problems will likely be forestalled and more complete system documentation will be available.

For more information on the Florida Solar Energy Center's design review program, please visit the site: <http://fsec.ucf.edu/pvt/BuyInstallPV/pvapprovals/>.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of the United States Department of Energy, Sandia National Laboratories, and the State of Florida Department of Community Affairs. Also, the valuable assistance of John Wiles of the Southwest Technology Development Institute of New Mexico State University, Roger Messenger of Florida Atlantic University, and Chuck Whitaker of Endecon Engineering is gratefully acknowledged.

REFERENCES

- [1] Grid-Connected Photovoltaic System Design Review and Approval, Operations and Procedures, Procedure # 7003 Version 5, FSEC-GP-70-01, 8 August 2002.
- [2] B. Farhi, FSEC Design Review Procedure, August 2002.
- [3] PowerMark Document PV 3.3: Design and Documentation Review and Evaluation Requirements for Grid-tied Residential and Small Commercial PV Systems.
- [4] National Fire Protection Association, NFPA 70: National Electrical Code 2002 Edition.
- [5] ASHRAE Standard 90.1-1999: *Energy Standard for Buildings Except Low-Rise Residential Buildings*, 24 June 1999.
- [6] IEEE Standard 929-2000
- [7] B. Farhi, FSEC Document: Template, August 2002.
- [8] B. Farhi, J. Dunlop FSEC Document: Design Review Checklist, August 2002.
- [9] J. Wiles, Photovoltaic Power Systems and the National Electrical Code: Suggested Practices, Sandia National Laboratories report SAND2001-0674, March 2001.