Solar American Board for Codes and Standards

Gap Analysis Final Report

July 28, 2008

Summary

The Solar America Board for Codes and Standards (Solar ABCs) Gap Analysis process reviewed the current state of the major codes and standards that bear on PV, identified major gaps that exist in the current work on codes and standards and prioritized these to become a strategic plan for the development of the Solar ABCs Annual Work Plan for Year 2 and future years.

From topics suggested by stakeholders, the Solar ABCs Steering Committee identified the following high priority topics to be addressed:

- Standardization of module power rating
- System Energy Performance Standard
- Standards to certify the accuracy of inverter meters
- Accelerated life testing for safety, reliability and durability of modules and the components used in modules
- PV Module frame grounding issues
- Roof-top PV module-specific fire research, testing and ratings systems
- National Fire Safety Guidelines for roof-top PV systems
- Revise building codes to address PV specifically
- Review and suggest updates to FERC interconnection screens
- Rate Impact of Net Metering

Many of the proposed activities will not happen without new funding from the U.S. Department of Energy.

Solar ABCs identifies current issues, establishes a dialogue among key stakeholders, and catalyzes appropriate activities to support the development of codes and standards that facilitate the installation of high quality, safe photovoltaic systems. It serves as a centralized repository for such documents, regulations, technical and "best practices" materials. It makes all materials and information easily accessible to the public and stakeholders.

Introduction

The Solar America Board for Codes and Standards (Solar ABCs) Gap Analysis process reviewed the current state of the major codes and standards that bear on PV, identified major gaps that exist in the current work on codes and standards and prioritized these to become a strategic plan for the development of the Solar ABCs Annual Work Plan for Year 2 and future years.

This report summarizes the method used to conduct the gap analysis, lists the potential topics identified, and establishes the priority topics for future work by Solar ABCs. Many of the proposed activities will not happen without new funding from the U.S. Department of Energy.

The Solar ABCs identifies current issues, establishes a dialogue among key stakeholders, and catalyzes appropriate activities to support the development of codes and standards that facilitate the installation of high quality, safe photovoltaic systems. It serves as a centralized repository for such documents, regulations, technical and "best practices" materials. It makes all materials and information easily accessible to the public and stakeholders.

The Solar ABCs changes the practice of developing, implementing, and disseminating solar codes and standards in the following ways:

- By providing formal coordination in the planning and revision of separate, though interrelated, solar codes and standards
- By providing access for stakeholders to participate with members of standards making bodies in setting national priorities on technical issues
- By developing a centralized repository for collection and dissemination of documents, regulations, and technical materials related to solar codes and standards
- And by creating a centralized home for three key technical services: a) generating consensus 'best practices' materials and disseminating such materials to utilities, state and other regulating jurisdictions, b) answering code-related questions (technical or statutory in nature), c) providing feedback on important related issues to DOE and government agencies.

The Solar ABCs works through Coordination, Implementation and Study Panels.

Method

The Gap Analysis was a major project for the Solar ABCs Steering Committee during the first year of the project. Stakeholders provided topics for consideration, the Advisory Committee and Steering Committee refined and prioritized the list of topics, and the Steering Committee developed the final list of high priority Gap Analysis topics.

Solar ABCs was launched with a stakeholder meeting on September 27, 2007 in Long Beach, California. Over 200 people attended this meeting including representatives from the solar industry, utilities, suppliers, and other interested stakeholders. During that meeting, participants learned about the first year activities of Solar ABCs. In addition, stakeholders were asked for their input on gaps or items that need improvement in the codes and standards processes related to photovoltaics. These suggested topics became the start of the Solar ABCs Gap Analysis Topic List.

Solar ABCs panels held Stakeholder Meetings in December 2007 and January 2008 and received additional suggestions for topics. As the Solar ABCs became known, additional stakeholders submitted proposed topics directly to the Project Administrator.

The Project Administrator compiled the list and sent it to both the Steering Committee and the Advisory Committee for review and discussion. These discussions led to combining topics, adding topics, and reorganizing the way the topics were presented in order to facilitate better review and prioritization. The final list of proposed Gap Analysis topics is included in Appendix A.

The Advisory Committee and Steering Committee each reviewed and prioritized the Gap Analysis list. The Project Administrator compiled the results.

Finally, the Steering Committee conducted a day and a half meeting to prioritize the Gap Analysis topics. The Steering Committee reviewed the individual rankings, discussed, and approved a list of high priority Gap Analysis Topics. Then the Steering Committee developed detailed suggestions for the activities needed for each of the high priority topics.

The Gap Analysis Process was led by the Solar ABCs Steering Committee and managed by the Solar ABCs Project Administrator, Larry Sherwood. The Steering Committee includes one representative from the following organizations: Arizona State University, BEW Engineering, Brooks Engineering, Florida Solar Energy Center, Interstate Renewable Energy Council, National Renewable Energy Laboratory, New Mexico State University, North Carolina Solar Center, PowerMark, Sandia National Laboratories, Sunset Technology, Underwriter Laboratories, and U.S. Department of Energy.

The Solar ABCs Advisory Committee includes: Jim Baak, Pacific Gas & Electric (also representing Solar Electric Power Association); Suzanne Borek, New Jersey Department of Community Affairs; Nick Chaset, California Public Utilities Commission; Adam Detrick, SunPower Corp.; Mark Dougherty, Long Island Power Authority; Smita Gupta, California Energy Commission; Edwin Iracki, DuPont; Tom McCalmont, ReGrid Power; Rhone Resch, Solar Energy Industries Association; Peter Varadi, Consultant; and Donald Warfield, BP Solar.

High Priority Gap Analysis Topics

Photovoltaic System Energy Rating

Objectives:
The tentative objectives are divided into the short-term (one year) objective and the long-term (3 to 5 Years) objective, as follows:

- The short-term objective is to develop and validate the procedure for *Simplified PV System Energy Rating* to provide annual system energy output for typical PV systems (focusing on residential and small commercial applications) using simple hourly simulation models.
- The long-term objective is to develop a process for validating PV models and pursue the process as a Standard.

Tasks:

<u>Task 1: Simplified PV System Energy Rating</u>
The procedure for determining the annual energy output of flat-plate grid-connected residential PV systems (up to 10 kWp), and possibly of small commercial PV systems (up to 100 kWp), under "optimal" conditions will be developed and validated to provide an estimate of PV system performance to homeowners, businesses, government and other renewable energy rebate granting agencies, just like the "EPA Vehicle Gas Mileage" or air-conditioners SEER. The procedure will be validated by the Project partners by comparing the predicted and actual measured PV system performance for at least three different module technologies (tentatively selected: crystalline silicon, multi-junction amorphous silicon, and CdTe) and at least three distinct climatic locations (tentatively selected: Florida, California, and Colorado/New Mexico/Arizona). This procedure can, then, be recommended by PowerMark Corporation to its approved certification agencies, such as FSEC, NMSU, and others to be used for certifying the annual energy output of specific flat-plate, grid-connected residential and small commercial PV system electrical designs. PowerMark approved certification agencies will provide the certified estimate of annual system energy output to the system designers, vendors, integrators, homeowners, businesses, government and other rebate granting agencies, at a nominal fee as requested.

The essential features of this task are:

1. PV module operational characteristics at different operating temperatures and irradiance levels will be input from the results of Gap Analysis Topic # 105 PV Module Power Rating/IEC 61853. IEC Technical Committee 82, Working Group 2 is currently working on *PV Module Power and Energy Rating* standard, IEC 61835, for flat plate PV modules. The draft of Part 1 on Power Rating is now under review by National Committees, including the US TAG. Part 2 on measurement techniques is expected to be circulated for review within 3 months. Part 3 on the methodology of energy calculation will be circulated for review by the end of 2008. This set of documents will form the basis of the procedure for *Simplified PV System Energy Rating*, when used in combined with PV system electrical design specifics and inverter operational characteristics, as described below. Solar ABCs Project partners will follow the progress of these documents and incorporate the methodology of the IEC 61853 in the procedure for *Simplified PV System Energy Rating*. In addition, FSEC

and ASU will validate the procedures in IEC 61853 by performing the test protocol on a representative set of module types.

2. Simple hourly simulation models like PV Watt, PV-DesignPro-G and PV Form will be used.
3. Only the optimum tilt (annual), direct south facing, 6-inch stand-off and direct-mount (including roof shingles) PV arrays with no shadowing (from vegetation, surrounding structures and row-to-row) will be covered.
4. PV system electrical design specifics, such as dc and ac conductor sizing and lengths, voltage drops across circuit breakers, disconnects, terminals etc will be included for the estimation of balance-of-system (BOS) power losses. Module mismatch losses will also be estimated.
5. Inverter operating characteristics, such as maximum power point tracking (MPPT) window, efficiency curve will be input in these simulations
6. PV system energy output will be predicted for at least five distinct climatic zones, such as (i) sunny, hot and dry (Phoenix, AZ), (ii) sunny, moderate and dry (Sacramento, CA), (iii) sunny, cold and dry (Denver/Golden, CO), (iv) sunny, hot and humid (Orlando, FL), and (v) partly cloudy, cold and humid (Boston, MA).

<u>Task 2: Requirements for Validating PV System Performance Simulation Models</u>

A number of PV performance simulation programs are available for predicting the output of a PV system. These programs range from very simple with few options for the user to select from to extremely sophisticated models with a daunting list of options and inputs. Some models are available free of charge; others can be purchased, while some are developed by system designers/integrators for their exclusive in-house use. Presumably, the developers of these models have performed some amount of testing and comparison to validate, at least to themselves, the results of their model. There is currently no standard method of evaluating the results from these models.

Under this task, Solar ABCs will develop a process for validating PV performance models. The process will likely include a set of system design characteristics, input weather data, and "actual" system performance. The design characteristics and weather data appropriate for the model under evaluation will be input to the model to provide a performance estimate and those results will be compared to the measured system performance. Several sets of design, weather, and performance data will be generated to address a variety of cell technologies, array configurations, and climatic conditions.

Comparisons will be made at the highest resolution offered by the simulation program (e.g., hourly) and at aggregated intervals (e.g., daily, monthly, or annual totals). Various measures of error will be provided and a set pass/fail criteria will be considered.

To accommodate a wide variety of modules, a very detailed set of data must be provided These required Validation Data fall into one the following three categories. Some examples of the type of data that might be need are shown under each.:

- **<u>Measured Weather Data</u>**

- Global horizontal irradiance, direct normal irradiance, plane-of-array irradiance , airmass, spectral distribution, ambient temperature, wind speed (at 10m height?) and wind direction, albedo, relative humidity, barometric pressure, water vapor, precipitation, aerosol, ozone, ultraviolet, date and time.

- **PV System Design Information**
  - Modules: cell technology, manufacturer, model, quantity, IEC 61215/61646 info, spectral response, temperature-irradiance characteristics from IEC 61853/Gap Analysis Topic 105, actual power rating, range and standard deviation of maximum power voltage and current for estimation of module mismatch power losses.
  - Array Electrical Design: modules/source circuit, source circuits/combiner box or subarray, combiner boxes or subarrays/array or inverter, number of inverters; wiring details: layout of combiner boxes, conductor sizes and lengths, BOS components (circuit breakers, disconnects, terminals) voltage drop and others.
  - Inverter: operational DC voltage range, DC maximum power point tracking window, operational AC voltage range, operational frequency range, start-up, shut-down, standby, nighttime losses.
  - Installation Configuration: system size, location, mounting type, installation details: fixed (tilt, azimuth) or tracking (one or two axes, axis orientation, axis tilt, tracking limits, back tracking), shadowing and soiling details.

- **Actual System Performance Data**
  - AC voltage, AC real and reactive power, DC voltage, DC current at source circuit level, subarray level, array level and system level, module temperatures, date and time.
  - Period: six-month minimum to include late winter and late summer, with spring preferred.

To accommodate the possible range of models that will be evaluated, an extensive and detailed Validation Data set will need to be defined. Actual input needs will be determined by the model under evaluation, and some standardized "rolling up" of parameters may be needed to ensure consistent use. It is anticipated that the Validation Data sets will start with actual systems that will be modified or further synthesized to ensure consistency and completeness.

Task 3: Submit Model Validation for Implementation as a Standard
This task will be conducted on the basis of the requirements developed and approaches decided in Task 2 beyond Year Two of the Solar ABCs Project. The national laboratories resources from NREL and Sandia, will be solicited for successful completion of this Task.

Standardization of Module Power Rating

Problem

PV modules are provided with a nameplate rating (in Watts at STC or Watts-Peak, Wp) and a tolerance band typically between ±3% and ±10%. Each module is flash tested at the end of the factory production line to establish its individual rating and, based on the tolerance band, assigned to a nameplate rating "bin" . Seeing such a tolerance band, one would expect a shipment of modules to, on average, equal the nameplate. However, an individual customer would have no recourse if all of the modules they received were at or just above the minimum rating defined by the lower bound of the manufacturer's tolerance. A major concern for PV consumers in the U. S. is the perception that the modules delivered to those consumers lacking any shipment-average requirements fall significantly below the nameplate, while modules delivered in Europe meet or exceed nameplate, on average [Atmaram, G., G. TamizhMani, G Ventre, "Need For Uniform Photovoltaic Module Performance Testing And Ratings", Proceedings of the 33rd IEEE PV Specialists Conference, May 2008].

This minimum rating is also used to define the starting point for allowable degradation for warranty claims, which means a particular module that

1. initially measures at the nameplate rating,
2. has a ±10% manufacturing tolerance (minimum power = 90% of nameplate), and
3. has a 20 year warranty specifying at least 80% of minimum power (72% of nameplate), can degrade at a rate of more than 1.63% per year (constant rate) and still be within the allowable warranty limits. Basing the warranty on the minimum power, in this case, allows nearly 50% higher degradation rate than if the warranty were based on nameplate (which would allow a 1.12%/yr degradation rate).

A third issue related to nameplate rating is that all PV modules are subject to an initial light-induced degradation (LID). For thin-film products, LID can be as much as 15-20% of initial power over the first 6-12 months of exposure. Crystalline products are also susceptible to LID ["A call for quality", Photon International, March 2008], though at typical levels of 1-4% and occurring over the first few hours of exposure to sunlight. While LID is almost universally reflected in thin-film module nameplate ratings well below the initial factor flash test results, crystalline products rarely if at all account for this known loss in their ratings. Module nameplate should fully account for LID in all technologies

Finally, the factory flash tests are subject to measurement uncertainties that can be as low as 2% or 3% in a well calibrated, well maintained system or as high as 10% if proper care is not taken.

Solution

Solar ABCs will take a multi-pronged approach to develop module power rating standards addressing each of these issues and implement them in the US market.

Task 1: Develop Proper Module Characterization Techniques

IEC Technical Committee 82, Working Group 2 is working on a Power and Energy rating standard (IEC 61835) for flat plate PV modules. The draft of Part 1 on Power Rating is now under review by National Committees, including the US TAG. Part 2 on measurement techniques should be circulated for review within 3 months. Part 3 on the methodology of energy calculation should be circulated for review by the end of 2008. This set of documents will form the basis of a power and energy rating. Solar ABCs will follow the progress of these documents and do what it can to facilitate the U. S. review and vote on them. In addition, ASU and FSEC will validate the procedures in IEC 61853 by performing the test protocol on a representative set of module types.

Task 2: Develop Standardized Module Rating and Reporting Requirements

The European community has established EN50380 entitled "Datasheet and nameplate information for photovoltaic modules". This document details the information that must be supplied with a PV module. This document requires the availability of module data at STC, NOCT and low irradiance as well as temperature coefficients. Upper and lower tolerances for maximum power must be provided. (The customer is then free to specify an acceptable tolerance for this.) All measurements should be after light induced degradation.

A U. S. document similar to EN50380 would provide a standard for module performance data. Customers could specify this document as part of the requirement for procurement. Therefore we propose the development of a U.S. Standard under IEEE SCC21 on "Datasheet and nameplate information for photovoltaic modules". One representative of Solar ABCs will chair this multi-year effort.

Task 3: Implementing Module Rating Scheme

PowerMark Corporation has established a procedure for third-party certification of PV module performance. This system has the following criteria:

1) Testing for the module power ratings should be done by an accredited, independent test laboratory.

2) Testing should be done on random sampling of modules from the marketplace (or production line).

3) The module nameplate rating tolerance should be based on the module nameplate power rating in accordance with the proposed U. S. standard, similar to the European standard EN 50380.

4) The module nameplate rating should account for LID.

5) The module nameplate rating should specify the maximum power degradation over module lifetime (for 20 or more years).

6) There should be some relatively simple (compared to the original testing) ongoing compliance check on the module nameplate rating on a periodic basis.

Under this task, the results of Tasks 1 and 2 would be incorporated into a Module Rating Scheme and implemented by PowerMark. An industry group consisting of module manufacturers, system integrators, private and public testing lab, NREL and Sandia will be actively involved to examine and review the scheme and promote its use by major funding institutions such as the California Solar Initiative and other state and utility-sponsored PV incentive programs.

Accelerated life testing for safety, reliability and durability of modules and the components used in modules

Problem

Crystalline silicon (c-Si) and thin-film (TF) photovoltaic modules are typically sold with 20-25 and 10-20 year warranty claims, respectively. However, there is, generally, no objective evidence with accelerated life testing to substantiate these warranty claims. In the absence of a publicly available accelerated life testing protocol or standard, the industry and consumers heavily depend on the qualification testing for the reliability/lifetime/warranty projection of the PV modules. Unfortunately, the qualification testing cannot be realistically considered as the reliability/lifetime testing.

The qualification testing is an excellent tool to identify major design issues and it may be considered as the preliminary/baseline requirement for the lifetime/reliability testing. As shown in Figure 1, the qualification testing does identify major/catastrophic infant mortality issues related to the module design [G. TamizhMani et al "Failure Analysis of Design Qualification Testing: 2007 vs. 2005", Proceedings of the 33rd IEEE PV Specialists Conference, May 2008] and the initial part of normal/useful life of PV modules in the field. In order to predict the lifetime of PV modules, the accelerated testing needs to be modified and extended much beyond the current qualification testing requirements. For example, a few manufacturers conduct the damp heat testing at 85°C/85%RH for 4,000 hours instead of 1,000 hours as warranted by the qualification testing standards. Therefore, it becomes important to develop one or more transfer functions for the lifetime prediction from accelerated testing; as expected, these transfer functions will be dependent on various influencing parameters such technology type, electrical configuration of the system and the weather conditions of the site. This work would initiate addressing the service life predictability, economics and consumer confidence.

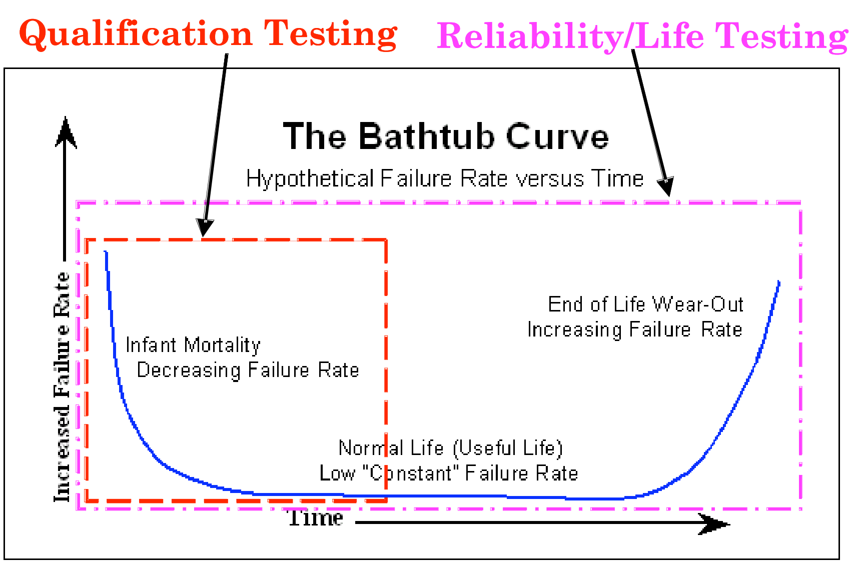

Figure 1: Bathtub curve for qualification testing and life testing

Proposed Solution

Establishing a correlation between time-to-failure in accelerated testing and time-to-failure in the field is a huge, multi-year undertaking, and it cannot be accomplished in a one-year study by Solar ABCs. This undertaking involves establishing a transfer function for each and every critical failure mechanism, e.g. corrosion and delamination in thin-film modules, and corrosion and solder bonds in c-Si modules. The eventual goal of this undertaking is two fold: (i) develop a standardized test protocol or a standard for the accelerated life testing of PV modules; and (ii) create a central clearinghouse (blinded database) on accelerated testing and failure data with a strong collaboration between the manufacturers, test labs, DOE, NREL, Sandia, and incentive providers (for example, energy commissions of the individual states) with privacy maintained on data sources. An approach will be taken in this one-year study period so that the above two goals could be achieved in 2-3 years timeframe. In this proposed one-year study, a detailed literature search will be carried and a draft test protocol will be developed as presented below.

Tasks

Task 1: Literature Search and Review: A large number of articles available in the public literature will be collected and reviewed to identify the common and major failure modes and mechanisms. A particular attention will be paid for the modules which underwent qualification testing and exposed in the field over 10 years. The sources for the literature collection would include:

- Long-term incentive providers including energy commissions of various states
- Utility companies including SMUD in California, APS and SRP in Arizona etc.
- Test laboratories including NREL, Sandia, FSEC, NMSU and ASU
- Proceedings of the reliability workshops organized by Sandia in 1990s
- IEEE-PVSC proceedings
- European Photovoltaic Conference proceedings
- Journals including Progress in Photovoltaics
- Conference tutorials organized in conjunction with IEEE-PVSC, and the SEMI and European conferences
- Models developed in the electronic industry including the Arrhenius models
- A systematic discussion with established module manufacturers under a strict confidentiality agreement

Task 2: Draft Protocol Development: At the end of this one-year study, a draft protocol will be developed which could serve as the basis for the development of a "Standard for Accelerated Life Testing or Recommended Procedure for Accelerated Life Testing" This comprehensive protocol will identify potential procedures to identify the failure modes and mechanisms. Since ASU-PTL is already an established facility for accelerated testing, PTL will attempt to collect a few of the old modules which had been type-tested for the qualification certification. These old modules will be subjected to the qualification testing or to the modified qualification testing for a correlation study. In addition to developing procedures, this study would develop preliminary transfer functions to correlate the accelerated life testing with actual field life.

Tasks

- Conduct an extensive literature search and review to identify various accelerated procedures, and failure modes and mechanisms
- Attempt to supply of a few field-stressed modules of various technology types and system electrical configurations
- Constantly interact and consult with NREL and Sandia to gain access to their database and literature
- Develop a draft protocol to serve as the basis for a future standard or recommended procedure / best practice
- Present the process in the "Solar Certification Forums" organized by IREC and the industry.

Standards to Certify the Accuracy of Inverter Meters

Problem

Solar photovoltaic power systems are most often being installed under net metering tariffs, which combine generated and consumed energy into a single "net" energy value. This simplifies the interconnection tariff and provides an economic incentive for consumers to install PV energy generation systems by valuing the generated energy at retail rates. However, other incentive programs are focusing on measuring the generation separate from the load in order to reward actions that improve total generation separately from actions that reduce load. For example, renewable energy credits are a marketable tender as long as they can be traced to energy production of an appropriate type of renewable energy source. Thus, in addition to the "net" revenue meter, a dedicated "production" meter is needed.

The challenge for residential-scale applications (less than 10kW) is that the cost of a separate energy production meter (~$90 for meter plus ~$40 for socket) is significant when compared to the profit margin available to the installer. Since these PV systems all include inverters that already measure power output in the course of performing their function, modifying these inverters to calculate the energy measurement is relatively simple, and in many cases manufacturers already offer energy generation measurement features. However, these energy measurements have been optimized for cost while still supporting acceptable energy conversion performance, and typically do not achieve the same level of measurement accuracy that a standard utility energy meter does (2%). Nevertheless, REC marketers and incentive program managers have indicated that there would be value in having available measurements certified at a 5% accuracy level for these purposes.

Standard utility revenue meters conform to standards such as ANSI C12.1, which defines tests to confirm that accuracy is maintained under a range of expected operating conditions (electrical and environmental). The California Public Utilities Commission has undertaken an effort to define a set of requirements that inverter-integrated energy meters will have to meet in order for recorded measurements from these sources to be acceptable for use in the Performance-Based Incentive program. While this scope is limited to a specific program in California, the goal of defining a standard set of requirements for inverter-integrated meters will be useful in any context where energy generated by grid-connected inverter-based power sources needs to be accounted for.

Proposed Solution

Create a standard set of requirements for integrated meters in inverter-based power generation systems. The proposed requirements defined by the CPUC will need to be reformulated in appropriate language to serve as a standard, and be guided through the process of review, integration of comments, and be voted on by an appropriate standards-making organization. Two distinct issues will need to be addressed: technical differences from existing standards arising from the use of a 5% accuracy requirement, and testing issues arising from having the meter integral with the inverter.

The scope of the proposed standard would be inverter-integrated metering. The requirements proposed by the CPUC have already identified that some requirements described by ANSI C12.1 Standard for Electricity Metering cannot be directly applied to inverter-integrated meters, but that in most cases similar requirements are already applied to inverters. Adding the integrated metering test requirements to an inverter standard or group of standards would be a logical next step. Both the IEEE Standards Coordinating Committee 21 (SCC21) and IEC Technical Committee 82 Working Group 6 (TC82 WG6) are possible venues for such a standard-making activity.

Tasks

1) Solicit input from the PUC and REC providers regarding their requirements for accuracy and inverter integration.
2) Assemble a Joint Committee of manufacturers, utilities, and other interested parties for review of the proposed standard language.
3) Submit proposed language to IEEE SCC21 or IEC TC82 for consideration as a standard.

Roof-top PV Module-specific Fire Research, Testing and Ratings Systems

Related to: Developing or revising a Standard

What is the major concern that this topic addresses?
The fire fighting commuity has concerns that roof-top PV modules may degrade the fire class ratings/fire resistance of roofing materials and promote unsafe conditions.

Why is this important and to what stakeholder groups?
Unnecessarily restrictive regulations may impeded the California solar market.

Who will benefit from remedying the concerns associated with this topic?
PV module manufacturers, installers, consumers, PV industry in general

What are the impacts of addressing this topic and for whom will these be favorable? Unfavorable?
Unfavorable – PV mfrs and supply chain could have increases in manufacturing costs if products have to be redesigned to meet increased fire rating requirements
Favorable – Industry will have scientific knowledge upon which to base requirements, legislation, acceptance, and move forward with assured safety.

Who else is working on this topic?
BIPV mfrs, UL proposed Solar ABCs fire testing project, other NRTLs and fire labs could possibly be working on this

Recommended Action to be taken by SOLAR ABCs:
1) Study to identify other entities working on this issue
2) Support UL's proposed Solar ABCs fire testing project (assuming it's good)
3) Deliver a white paper

National Fire Safety Guidelines for Roof-top PV Systems

Related to: Developing a Model Policy

What is the major concern that this topic addresses?
Firefighter safety, building fire safety, installation procedures and permit requirements

Why is this important and to what stakeholder groups?
It could streamline process, reduce costs and answer concerns of fire marshals; Stakeholders are 1) PV industry; 2) Fire Marshals; 3) Building officials; 4) Other stakeholders like insurers, builders, utilities, etc.

Who will benefit from remedying the concerns associated with this topic?
Same stakeholder groups

What are the impacts of addressing this topic and for whom will these be favorable? Unfavorable?
Favorable – For firefighters, it will streamline guidelines; for building officials, it will streamline permitting processes;
Unfavorable –it will now impose new guidelines/restrictions on fire class rating of PV products and requirements restricting PV from areas of the roof for access and ventilation.

Who else is working on this topic?
California State Fire Marshall and working group

Recommended Action to be taken by SOLAR ABCs:

- Draft a guidebook to the California State Fire Marshal Guidelines for Solar Photovoltaic Installations so that key stakeholders in other state can understand the context of the guidelines and understand how best to implement information from the guidelines. Given the wide variety of fire protection techniques, the application of the guidelines will vary significantly.
- Convene a group of fire officials and PV industry representatives to address testing needs of fire officials to understand various hazards when fighting fires on structures with PV systems (Brooks).

Revising Building Codes to Address PV Specifically

Problem:

The PV industry currently relies on the various interpretations of building codes by licensed structural engineers to design PV mounting systems. Alternatively, custom testing methods may be used and approved by a structural engineer and may include wind tunnel testing or computer simulations. This has resulted in a multitude of code interpretations, yielding different answers to the same design questions, as well as faulty test data being inadvertently applied to PV mounting systems.

The American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures (ASCE 7) is the most comprehensive wind design standard in the U.S. Other building codes, such as the International Building Code (IBC) contain wind design requirements, but are less comprehensive, especially for design problems with atypical building geometry, as is the case with roof-mounted PV systems. Fortunately, the IBC and other building codes explicitly permit the use of the ASCE code for the design of buildings and structures.

A recommended approach for the structural design of roof-mounted PV systems, based on the ASCE standard 7-05 has been developed under the Solar ABCs project. Examples are provided to demonstrate a step-by-step procedure for calculating wind loads. The approach is applicable to PV modules mounted on rooftops under 60 feet, when oriented parallel to the roof surface. An approach for PV modules oriented at an angle to the roof surface presents a more complex scenario and requires further research and testing.

The procedure for determining wind loads on buildings and structures is described in Chapter 6 of the ASCE standard. A thorough review of the code was conducted under the Solar ABCS project by a team of experts in the areas of PV system design as well as aerodynamics, wind tunnel testing, and the ASCE standard. The team was able to conclude that there is no prescribed method in the standard that specifically addresses the specific geometry of roof-mounted PV systems and design professionals are left with little or no guidance.

The problem of not having accurate internal pressure coefficients for common PV geometries is a key weakness in applying the standard to roof-mounted PV systems. However, making a conservative assumption, the team is confident that the wind loads on a roof-mounted PV system parallel to the roof can be estimated with the Section 6.5.12.2 of the ASCE standard.

Although some Figures in ASCE-7 have geometries that appear to be similar to tilted PV modules, is not recommended to apply this section to modules oriented at a tilt relative to the roof surface. None of the referenced Figures adequately address the geometry tilted PV, which is inherently non-aerodynamic, mounted on top of a building.

Proposed Solution

Additional work is required to understand the actual forces on roof mounted PV arrays. Without this basic information, the industry is left exposed to significant liability for structural failures of modules and mounting systems. Or, the consumers are potentially paying for site-specific engineering fees, conservative calculation errors, additional hardware expense, and extra labor costs. Wind tunnel testing is required to collect empirical data that will establish the relationship of the wind forces on the PV arrays. This information can be used to calibrate models that will allow designers to more effectively assess the loads applied to the modules, mounting structure, and the building.

The project team for the Solar ABCs year 2 wind loading on PV arrays task will include existing members from FSEC and BEW. Additionally, researchers from the Florida International University International Hurricane Research Center will provide the team with a means to evaluate wind loads at full and partial scale. Industry partners will also be included to provide products and possible leverage funding to assist with the development of the work.

Tasks:

Task 1
Wind Tunnel Testing for Roof Parallel Mounted PV Modules and Arrays
Scope
Wind tunnel testing will be conducted to determine the flow field and wind induces forces on PV modules and arrays mounted parallel to the slope of the roof surface. Data obtained from this testing will be used to calibrate numeric models and assess various array types and geometries.

Task 2
Recommended Additions or Changes to the Code
Scope
The empirical data and calibrated models developed under Task 1 will be used to directly address the wind forces on roof parallel PV modules and arrays. Recommendations will be made for changes or additions to the applicable codes based on the findings of the research. Reports and professional papers will be published.

Task 3
Guidance to Design Professionals for Roof Non-Parallel Mounted PV Modules
Scope
Documentation or publications will be made to offer recommended practices or calculation methods for applying the existing codes to cases where the PV modules or arrays can not be mounted parallel to the roof surface. The documents will offer sample calculations and suggestions for designing a code compliant project. This information will serve to fill a void that currently exists for designers and code officials.

Rate Impact of Net Metering

Related to:

- Developing a Best Practice
- Developing a Model Policy

What is the major concern that this topic addresses?

Penetration levels for net metering are set low (< 2.5% in CA and far less in most states), creating a barrier to deployment. By determining the rate impact and the non-monetary impacts at different penetration levels, a reasonable argument for higher penetration levels can be developed with negligible impact on utility profits. This determination must include impact of TOU rates and demand charges.

Rate impacts include the effects of reduced daytime energy generation, reduced T&D capital costs and eliminated line losses. Non-monetary items requiring valuation include the effect on carbon emissions and health impacts.

Why is this important and to what stakeholder groups?

Need the study to justify increased penetration levels for state net metering programs and support full net metering.

Who will benefit from remedying the concerns associated with this topic?

- Users and industry (manufacturers, installers, etc).
- Utilities through experience with interconnection of PV systems, which may be part of utility Integrated Resource Planning.

What are the impacts of addressing this topic and for whom will these be favorable? Unfavorable?

All favorable:

- Users – need fixed cost/benefit analysis that includes benefits of net metering
- Industry (manufacturers and installers) – want to sell more product and services
- Investors and lenders – want return and certainty
- Utility Commissions – concerned about fairness to parties / cost allocation
- Utilities – concerned about lost revenue, will benefit from hard data

Who else is working on this topic?

Studies conducted in California in the 1990s addressed net metering impacts on rates for low-level penetration (0.1%).

Recommended Action to be taken by SOLAR ABCs:

Perform the study discussed here.

Review and Recommend Updates to FERC Interconnection Screens

Related to:
- Developing a Best Practice
- Developing a Model Policy

What is the major concern that this topic addresses?
Several screens for fast track interconnection in section 2.2.1 of FERC's Small Generator Interconnection Procedure (SGIP) may be unnecessarily restrictive. Refining that list to simplify interconnection can reduce a barrier to solar energy installations. The SGIP screens are adopted in many state and utility interconnection standards, so the effect will extend far beyond FERC-jurisdictional lines.

Why is this important and to what stakeholder groups?
Important to update screens because it will simplify the interconnection process based on lessons learned after 40,000+ solar installations.

Who will benefit from remedying the concerns associated with this topic?
See below

What are the impacts of addressing this topic and for whom will these be favorable? Unfavorable?
All favorable:
- Users – simplified interconnection
- Industry – more sales
- Utilities –simplified process lowers costs
- Commissions – guidelines for state standards

Who else is working on this topic?
State public utility commissions and utilities consider the screens, but have little guidance for deviation from the screens. IEEE 1547.6 is working on spot network interconnection (one of the SGIP screens).

Recommended Action to be taken by SOLAR ABCs:
Perform the study discussed here and present to FERC. Work with related parties – IEEE, EEI, SEPA, NARUC.

PV Module Frame Grounding issues

Problem:

PV modules are typically installed on structures made of galvanized, painted, or stainless steel, or aluminum. These structures and any other electrically conductive components that could become energized by the PV array, and that could be accessible during routine servicing, must be bonded to a common earth ground. The National Electric Code (NEC) does not provide guidance on how metal parts should be bonded together to provide a reliable ground, and it is outside the scope of the Underwriters' Laboratories (UL) 1703 Standard for PV Modules. To our knowledge, there are no industry guides on how to design, install, and maintain a reliable electrical bond between metal parts in outdoor environments for 20+ years, leaving the installer with no option but to improvise solutions to this problem.

The result has been a surprisingly large number of fielded systems that (a) violated the module's UL listing by not complying with the installation manual's prescribed method of grounding the module frame; (b) did not result in an electrical connection between components, leaving module frames and/or the structure ungrounded, and/or (c) did create an electrical connection but the method was nevertheless improvised, with no testing, field validation, or certification to verify that the newly made connection would last for the design life of the system. Many of these fielded systems were inspected and approved by local building authorities, including an occasional system with no equipment ground to the structure or module frames whatsoever.

Current practices pose a life safety risk to maintenance and emergency response personnel, and complicate permitting and inspections due to the lack of clarity in what constitutes acceptable design practices. A serious injury or death resulting from an improperly grounded PV structure would be a tragedy, to say the least. Such an event would also carry ramifications for the entire industry, millions of dollars in liability (per death or injury), negative publicity for PV in general, and an increase in complications in obtaining permits.

Proposed Solution

A simple and practical "recipe" for equipment grounding of PV components be documented and made available to the public for the purpose of bringing clarity to this issue. Test methods will be developed for the purpose of evaluating the long-term reliability of the ground connections between metal parts in a PV array. The results will be applicable to any roof-or ground mounted PV array mounted on metal structures.

Tasks

The specific tasks are broken down as follows:

1. Define requirements: the technical requirements for a ground connection will be established. For example, array voltages and currents will be bracketed,

environmental conditions, and allowable electrical resistance between metal parts will be defined. This work will be done collaboratively between BEW and Tim Zgonena at UL.

2. Industry research: UL, utility engineers, and other industry experts will be surveyed for their experiences with this issue. Examples of successes and failures of similar applications will be studied. BEW will lead this effort.
3. Development of test methods: UL will lead the effort to identify test methods to evaluate long-term grounding solutions.

Appendix A

Suggested Gap Analysis Topics

ID#		Topic Recommendation	Suggested by
	STANDARDS		
	Needed Standards		
100		System Energy Performance Standards	ASTM E44.09 (Mani), Brian Sagar, Nanosolar, David Sweetman
101		Limitations in the *NEC* for determining the ampacity of conductors operating over 80 degress C.	
102		Standards on Manufacturing Safety Practices	Adam Detrick
103		Standards for Installation and Operation	Suzanne Borek
		Standardization of module characteristics:	
104		Both NOCT and other "normal operating temperature" test methods (i.e. in UL 1703) are performed in the open circuit condition. This significantly overestimates actual operating temperature, particularly as efficiency rises.	Adam Detrick
105		Standardization of module power ratings. Different mfg use different calibration labs, tolerances and policies on what the nameplate label is relative to actual module power. This is unfair to the end consumer who is forced to compare apples with oranges.	Adam Detrick
114		Test standards for non-PV solar technologies (apart from solar thermal). Safety, reliability and performance testing standards. Examples are dish sterling technology and solar thermal for absorption chillers.	Smita Gupta
111		User education standards, e.g. specify, use, test, measure, install, operate, maintain, integrate, connect, analyze, trouble-shoot, repair	David Sweetman
118		Accelerated testing. There is a lot of evidence that the current accelerated tests in IEC and UL don't replicate actual product lifetime expectancies (i.e. 25 year warranties). However, there is also the issue that certification time is already a heavy burden on the PV industry with respect to introducing new products and innovating. Perhaps this can get discussed in the context of UL being an industry bottle neck and the needed for expanded testing facility and acceptance of other NRTLs.	Adam Detrick
106		EVA Gel Content Test Method Validation (Need to make standard acceptable for PV manufacturer)	ASTM E44.09 (Mani)
107		Standard for PV and solar hot water specialty licenses (Is this in Solar ABCs scope?)	Stakeholder Meeting
108		Standards for variance control and reliability	David Sweetman
109		Standards for connections between equipment including hardware, firmware, software	David Sweetman
110		Standards for packing, labeling, shipping and recycling	David Sweetman
112		Standards for CPV Tests (covered in current study?)	Nick Chaset
113		Accelerated life-time testing of thin-film modules	
115		Manufacturing Waste Practices: Defined standards on manufacturing waste stream and subcontractor waste management (follow up from Washington Post article on Poly waste disposal)	Adam Detrick
117		Standards for shipping & recycling –consider voluntary industry product take-back standards as well.	Adam Detrick
178		UL should consider developing a generic method for testing clips so that manufacturers do not have to test every combination of clips with every module	
179		Clairfy the boundary between UL listing and local permitting requirements.	
	Standards/Certification Process		
119		Concern about new UL test facility and near monopoly of UL with testing	Steve Coonen, Open Energy
120		Significant Interpretations from UL are onerous and in some cases require UL lab testing. Not fair for other NRTLs who may interpretate differently. Changes of this magnitude should be run through STP and written into standard.	Adam Detrick
121		Overall certification process takes too long	Stakeholder Meeting
122		Standards Committees should meet more frequently - need to move quickly to support industry.	Stakeholder Meeting
123		Need cell qualification process (Why do component testing if you still have to do module testing?)	Stakeholder Meeting
	Certification/Qualification		
124		Need accelerated life testing for reliability and durability of modules and the components used in modules	Mani Tamizh-Mani
125		Need EnergyStar or EnergyStar-like certification or mark for module and/or system performance	Mani Tamizh-Mani
	Inverter Meters		
126		Standards to certify the accuracy of inverter meters. Needed to certify RECs and other applications. California is currently developing requirements. Need for CSI and maybe also for WREGIS REC trading.	Nicolas Chaset, Jim Baak

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127	Solar and the smart grid. Study the potential interplay between solar systems and Advanced Metering Infrastructures (subject of current study)	Nick Chaset
	CODES	
	Fire Safety Issues	
128	Fire Rating of PV Laminates - PV laminates must only meet Class C fire rating, which is not appropriate for roofs in the Western US. Comment: There is no evidence that anyone has brought forward which indicates that a lower fire class PV module negatively impacts a the fire rating of a higher classed roof. This is being addressed with UL and their white book statement.	Steve Coonen, Open Energy
129	National Model Fire Safety Guidelines (so California Guidelines do not become the national model)	
130	Testing for fire safety. Generic testing to answer questions firefighters have about interaction of PV and structural fires.	
131	Fire Codes vs Electrical Codes when dealing with batteries	
	Model Codes	
132	Model code should be developed for seismic areas (Some stakeholders thought this is not necessary)	Stakeholder Meeting
133	Model building codes regarding PV	DOE FOA
134	Model checklists for permit structural information	Jeff Wolfe, groSolar
	Building Codes (non-electrical)	
135	Coordinate with ICC-ES, the code writing authority for construction materials -- ICC-ES Code AC365 for BIPV roofing materials. Issues about snow loading and wind and seismic loads. Comment: Agree that there should be coordination with ICC in terms of writing model building codes but ICC-ES actually doesn't write code. They evaluate products.	Steve Coonen, Open Energy
	INTERCONNECTION AND NET METERING	
	Utility Rate Design/Net Metering	
136	Southern California Edison rate structure restrictve and negative for systems 1-5 MW	Solar Cities through A. Rosenthal
137	Residential Rate Structures and Solar (AB1x/flat or volumetric rates vs. TOU rates)	Nick Chaset
138	Assess the interaction between demand charges, demand rachets and net metering benefits	DOE FOA
139	Rate Impact of Net Metering	Stakeholder Meeting
140	Economics of net metering	DOE FOA
141	Study the economic difference between TOU net metering vs. flat-rate net metering, perhaps in a few select utilities' service territories	Rusty Haynes
142	Study the potential impact of feed-in tariffs or other similar production-based incentives on net metering	Rusty Haynes
143	Many coops do not allow net metering	David Sweetman
	Interconnection	
144	Usefulness of interconnection "screens" for quick approval of installations by local authorities, including BIPV	DOE FOA
145	Review of FERC and California Interconnection Screens (part of current study?)	
146	Review of costs associated with different interconnections standards (Ca's Rule 21, FERC Small Generator Interconnection Protocol). In CA, solar participating in CSI is subject to fast-track interconnection (no interconnection study), whereas through AB 1969 feed-in tariff, generators are subject to FERC SGIP, and therefore may have to bear the costs of interconnection studies and system upgrades.	Nick Chaset
147	Coops should, but do not have to, follow FERC rules	David Sweetman
148	Common SW & HW connection protocal from all inverter manufactures: Mechanical connection, refresh rates, minimum data transferred.	Adam Detrick
	GENERAL OR CROSS-CUTTING	
	Installation Guidance/Best Practices	
149	Provide guidance for sizing line-side interconnection conductors	Stakeholder Meeting
150	Information on large commercial system GEC sizing	Stakeholder Meeting
151	Best practices for solar thermal permits and inspections - wide variation in Minn. Some require 3 inspections (plumbing, mechanical, structural)	Stacey A. Miller, Minnesota Dept. of Commerce
152	Work with OSHA to get roof safety issues before PV stakeholders	Stakeholder Meeting
153	Mandating freeze protection for solar thermal	Nick Chaset
	BIPV Issues	

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154		Please address BIPV and building-applied modules versus rack-mounted modules as it applies to operating temperature, grounding, fire, etc.	Stakeholder Meeting
155		Develop research agenda to create data on which to base BIPV Standards related to NOCT test. Could be based on CEC specifications.	Chuck Whitaker, Smita Gupta
156		Add BIPV to list of issues for Product Safety Panel	Stakeholder Meeting
157		Parametric certification of BIPV	DOE FOA
158		Include in NEC: BIPV Issues	DOE FOA
	Grounding		
159		Grounding and bonding. Need to clarify requirements and avoid onerous requirements brought forth by UL significant interpretations.	Stakeholder Meeting
160		Need for training on proper design of grounding systems	Stakeholder Meeting
161		Grounding problems in harsh climates	
162		Grounding products – *proposal made to UL STP on this issue.*	Brian Wiley
	Performance Study		
163		Study the effects of airborne debris on PV modules or solar heating panels. Is this in regards to soiling or impact resistance/reliability?	
164		Recommendations for cleaning dust.	Stakeholder Meeting
165		Study the effects of shading on PV performance. In particular in the context of PV Incentive Programs where incentive calculators that include shading calculations.	Nick Chaset
166		Thermal interaction of BIPV with the building envelope and the effective heat transfer through the building element into the conditioned space	Smita Gupta
	Utility-Scale Solar Policies		
167		Large Generator Interconnection Policies and Procedures	Jim Baak
168		Streamlined Environmental Permitting	Jim Baak
169		Renewable Energy Transmission Access Policies & Procedures	Jim Baak
	Solar ABCs PROCESS/PRODUCTS		
170		Create a SAI central library - one web library for all data.	Stakeholder Meeting
171		Collect completed studies from other sources (CPUC, SEIA, etc.)	Stakeholder Meeting
172		Conduct web/phone seminar on key issues with experts	Stakeholder Meeting
173		How can states compare notes on what works and does not work?	Stakeholder Meeting
174		How to make standard and code processes more transparent?	
	UNSURE WHAT IS REQUEST		
175		Billing Systems	Stakeholder Meeting
176		Semi-conductor based disconnects: right now, a solid-state wwitch is not allowed as a system disconnect	Stakeholder Meeting
177		What tools, methods, knowledge, training is required to design, assemble, install functional systems – handbooks for designers, installers, users	David Sweetman
	REMOVED FROM GAP ANALYSIS CONSIDERATION		
		North American version of IEC 61730 (UL is working on this and it is near release)	
		These items no longer relevant with new California Guidelines?	
		Fire marshalls want quick release or hinged systems for tilting up modules on roofs	Stakeholder Meeting
		Fire issue: differentiate between HVDC, LVDC, AC Modules, systems with active shutdown	Stakeholder Meeting
		Smoke detector can be used to turn-off the inverters and PV system in case of fire	Stakeholder Meeting