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CODES, STANDARDS, AND PV POWER SYSTEMS A 1996 STATUS REPORT

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ABSTRACT

As photovoltaic (PV) electrical power systems gain increasing acceptance for both off-grid and utility-interactive applications, the safety, durability, and performance of these systems gains in importance. Local and state jurisdictions in many areas of the country require that all electrical power systems be installed in compliance with the requirements of the *National Electrical Code®* (*NEC®*)[1]. Utilities and governmental agencies are now requiring that PV installations and components also meet a number of Institute of Electrical and Electronic Engineers (IEEE) standards. PV installers are working more closely with licensed electricians and electrical contractors who are familiar with existing local codes and installation practices. PV manufacturers, utilities, balance of systems manufacturers, and standards representatives have come together to address safety and code related issues for future PV installations. This paper addresses why compliance with the accepted codes and standards is needed and how it is being achieved.

INTRODUCTION

PV systems, in many cases, are operated by the general public, requiring those systems to be at least as safe and as easy to operate as any other electrical power system or component. In fact, since PV systems represent a relatively new and usually unfamiliar technology, they may have to be easier and safer to operate and maintain than other power systems to gain wide acceptance. Ensuring that all PV systems comply with all applicable codes and standards will go a long way toward establishing that objective.

PV systems, which are installed by connecting various components (modules, batteries, inverters, etc.) in the field, generally are covered by the provisions of the NEC or other code. Such installations require that all equipment be examined for safety and be listed to standards established by Underwriters Laboratories Inc. (UL). Many utility companies are requiring NEC compliance for safety and to reduce liability issues. Utilities and governmental agencies are now requiring that PV systems and components meet a number of IEEE standards in addition to complying with the NEC. These increasing demands that PV systems meet a variety of codes and standards are causing the PV manufacturers to design and manufacture products that satisfy these requirements. PV installers are working more closely with licensed electricians and electrical contractors who are familiar with existing local codes and installation practices.

While non-standardized equipment that is installed using unconventional techniques may not necessarily be unsafe, the need to meet the laws of various jurisdictions and the liability issues associated with non-standard installations dictate that codes and standards be followed. Furthermore, the typical electrical inspector has expectations such as good workmanship, listed components, clearance spaces, disconnect locations, etc., that are not always well addressed by the PV industry today.

Codes and standards relating to PV systems provide a reasonably clear set of guidelines for the PV industry. However, a thorough understanding of the NEC and PV systems is required to design and install safe, reliable, and durable systems.

PV, THE CUSTOMER, AND THE INSPECTOR

PV systems, both off-grid and utility-intertied, are being installed throughout the country in full compliance with the NEC. Compliant systems are often installed in response to purchases by utilities and government institutions. Enlightened individuals are also requesting code compliance and, in some cases, they are responding to the requirements established by building permits and/or financing and insurance for the systems. These systems use components that are listed to UL Standards, are installed following the requirements of the NEC or local codes, and are being inspected by the authorities having jurisdiction who find them in compliance with local and national codes. These systems offer safety for the installer, user, and maintainer while usually providing high levels of performance coupled with durable, reliable operation.

Electrical inspectors (as authorities having jurisdiction) have the final word on what is and what is not acceptable. They expect to see good workmanship that resembles the long-established standards for commercial and residential electrical power systems. They also expect to find listed components, but there are still more unlisted, non-standardized PV components on the market than there are listed components. While there may be a formal appeal process available, the ruling of the local inspector is usually supported in the appeal.

CODES AND STANDARDS

The NEC and supplemental state, county, and municipal electrical codes govern the installation of PV power systems just as they govern the installation of other electrical power systems. These systems are required to have components examined for safety, which means that the components must be manufactured and tested to UL standards.

While codes are generally documents that are legally mandated, standards are documents that are specified in the procurement process for PV systems. Government agencies (federal, state, and local) and utility companies usually specify standards to ensure that the final system meets the performance requirements established by the standards. Large commercial or industrial customers often use various standards in the procurement process.

Standards and codes are the product of many people working countless hours using professional experience and a knowledge of the current technology to write requirements and guidelines that will result in safe, durable, and high performance electrical power systems, including PV systems. These standards and codes are the joint product of a collaboration among the PV industry (for codes and standards affecting PV systems), the balance of systems industry, standards developers like UL, the academic community, electrical inspection officials, and government agencies with input from the end user.

The National Electrical Code

The NEC is published by the National Fire Protection Association (NFPA), and establishes the installation requirements for nearly all electrical power systems that are installed in the field. The NEC, nearly 100 years old, is reviewed and updated every three years. Utility-owned generation, transmission, and distribution systems are not covered, but any stationary privately-owned or commercial power system is covered as is all premises wiring. PV systems owned and operated by a utility on private property have been deemed to fall under the NEC. The NEC covers systems with voltages from zero to 40,000 volts and frequencies from direct current to radio frequencies.

Because PV systems are electrical power systems, most of the requirements in the NEC pertain to PV systems. The complexity of the NEC and the implications of existing NEC requirements for PV installations dictate that PV dealers and installers become or work with licensed electricians or electrical contractors. These organizations should have complete knowledge of the NEC and PV installation requirements.

In the past, PV systems have been designed by PV-cognizant companies with little NEC experience which have violated NEC safety provisions. In a similar vein, large PV systems have been designed by electrical contractors with no PV experience that had lower than expected performance and were found unsafe for personnel and equipment. Since safety, durability, and reliability are the main goals for all PV systems, there is a strong incentive to gain the necessary knowledge through team work.

NEC Article 690 – Solar Photovoltaic Systems

Article 690, consisting of 10 pages in the 1000+ page 1996 NEC, deals specifically with PV systems. In cases where the Article 690 conflicts with other articles in the NEC, Article 690 prevails. The unique aspects of the PV source (light and temperature dependent current source) dictate that particular attention must be directed at sizing and rating the cables, switchgear, and overcurrent devices associated with the PV module or array output.

Storage batteries used in stand-alone systems, while often rated at low (12-24v) voltages, pose significant hazards if not installed properly. The stored energy and potential short-circuit currents of batteries must be considered when applying fuses, circuit breakers, and cables to stand-alone PV systems.

Other Codes

PV equipment and systems may be impacted by a number of other codes. For example, local, state, and municipal codes may supplement the NEC. Both the NEC and local codes require that all equipment in an electrical power system be examined for safety. The authority having jurisdiction has the responsibility for this examination, but readily elects to require the use of listed and labeled equipment. Listing and labeling is the process by which equipment is tested for safety by a recognized (by the authority having jurisdiction) testing laboratory.

UL Standards

The testing laboratory (e.g. UL, Inchcape Testing Services (ETL), Canadian Standards Association (CSA)) tests products for compliance with safety standards that have been published by UL. Any electrical equipment that is to be tested and listed has to pass a number of specific safety standards. Equipment may be listed against a single standard such as UL-1703 [2] for PV modules and UL 1741 [3] for inverters and charge controllers. However, imbedded in the single standard are numerous requirements from other UL Standards relating to such things as screw sizes, materials, torque values, cable sizes, insulation, etc. If a specific, single standard does not exist for a product to be listed, then several existing standards will be applied during the listing process.

In general, the maximum use of listed or UL-Recognized parts and sub components in a product will reduce the cost and time required to obtain a listing from a testing laboratory. The use of new, non-recognized or non-listed materials will necessitate additional testing, expense, and time.

NEMA Standards

Most electrical power systems use enclosures that conform to standards established by the National Electrical Manufacturers Association (NEMA). These enclosures (e.g. NEMA styles 1, 3, 3R, 4, 11, and 12) are

familiar to the electrical inspector. PV manufacturers sometimes use custom enclosures for product appeal and identification. The use of these non-standardized enclosures may hinder the inspection process.

IEEE Standards

IEEE Standards dealing with the installation and performance of PV modules and the batteries commonly used in PV systems are developed primarily by IEEE Standards Coordinating Committee 21. The IEEE Standards are developed by teams of stakeholders including many volunteers from the PV industry. In many cases, the IEEE Standards establish performance as well as safety requirements in contrast the UL Standards that deal primarily with safety (fire and shock hazards).

A number of draft standards are being prepared and coordinated by IEEE and UL. They deal with module qualification, inverters, charge controllers, and batteries. These standards, when completed, will provide the PV industry with better design and installation guidelines for both equipment and systems. An IEEE Guide for PV module qualification [4] was published by the IEEE this year. Additional Guides and Recommended Practices for PV safety and field testing as well as reaffirmations and modifications of existing standards are being worked on.

STATUS OF PV-RELATED PRODUCT LISTINGS

Listing of PV-related components is on the increase with quantities of listed products increasing, but a quantitative assessment of the dynamic process is difficult. The numbers of manufacturers of PV-related products have increased as manufacturers have become cognizant of the PV market, but many of these manufacturers have not yet listed their products. Many smaller manufacturers do not advertise or distribute their products nationally and may not be counted in this evaluation. Some products have been listed and then manufacturing has been discontinued. Tables 1 and 2 summarize the number of PV-related manufacturers that had or have listed products in 1989 and in 1996. These tables do not count the number of listed products, but count the numbers of manufacturers that have at least one listed product in the categories shown. The tables are limited to PV-related hardware and do not include manufacturers of electrical switchgear, overcurrent devices, or cables.

Table 1. Manufacturers of Listed PV Hardware - 1989

PRODUCT CATEGORY	Mfg.	Listed	%
Modules	4	2	50
Charge Controllers	6	0	0
Inverters	7	2	29

Table 2. Manufacturers of Listed PV Hardware - 1996

PRODUCT CATEGORY	Mfg.	Listed	%
Modules	12	5	42
Charge Controllers	11	4	36
Inverters	10	4	40

The tables show that the number of balance of system component manufacturers (of charge controllers and inverters) and the percentage with listed components have increased significantly between 1989 and 1996. While the numbers of PV module manufacturers have increased, the percentage with listed products has decreased.

It has been observed that the manufacturers having listed products have a significantly greater market share than those with no listed products. In addition to increased market share, the production of listed components that are installed in full compliance with the NEC or other codes reduces liability issues for the manufacturer, dealer, and installer. Field testing has shown that code-compliant PV installations are usually safer and more durable than those systems not complying with the codes. Because of the rigorous testing and established installation methods, these code-compliant installations have also been found to be more reliable. Failures in code-compliant systems have been easier to find and repair.

1996 AND BEYOND

A total of 26 changes were made to Article 690 for the 1996 NEC. Those changes include definitions, grounding, voltage ratings, overcurrent devices, disconnect requirements, battery charging and installation, cable sizing and types, and clarification of language. Several changes were made in other sections of the NEC that affect PV systems. They include cable marking and grounding. Most of the changes for the 1996 Article 690 were developed by a Task Group that was established by the National Fire Protection Association (NFPA) through Code Making Panel #3 (responsible for Article 690) for the NEC. The Task Group consists of nine members coming from a mix of the PV-related industries, UL, the Solar Energy Industries Association (SEIA), and the national laboratories. This Task Group is closely supported by the SEIA Technical Review Committee for Standards and Codes (TRC) that consists of more than 50 members from the PV industry. All actions and proposed changes submitted by the Task Group are approved by a consensus vote of the TRC.

This Task Group has been directed by Code Making Panel #3 to examine Article 690 and propose changes for the 1999 NEC needed to bring it in line with the available PV technology. The Task Group and the TRC have already written proposals to address the new AC PV Module, building-integrated PV installations, installations over 600 volts, marking requirements, cable sizing requirements, and the affect of temperature on module open-circuit voltage. Work is continuing to meet the submission deadline in November 1996.

Workshops and seminars for electrical inspectors, PV manufacturers, dealers and installers, electrical contractors, utilities, and government agencies are being held throughout the country on a regular basis. More than 30 presentations have been made in recent years. A suggested practices manual relating PV systems to the NEC has been published and is updated annually [5]. Magazine articles on PV and codes and standards are published for the PV dealer and installer and the electrical inspector.