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CATEGORY 6D - ORAL

PHOTOVOLTAIC INDUSTRY PROPOSED CHANGES FOR THE 1999 NATIONAL ELECTRICAL CODE FOR PV APPLICATIONS*

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Abstract

An industry supported task group has recently completed writing proposals for changes to bring Article 690 of the 1999 National Electrical Code (NEC[®]) up to the state-of-the-art in photovoltaic device and system technology. This paper summarizes proposed code changes, discusses background on both new and changed, and presents examples for the proposed changes. Topics such as the proposed new temperature compensation table for calculating maximum system voltage are analyzed. Procedures for calculating conductor sizes with the proposed changes are presented. Impacts on photovoltaic installations, building integrated systems, and AC module installations are also analyzed.

Introduction

Collaborative work to write proposals for changes to bring the Article 690 of the 1999 NEC up to the state-of-the-art in photovoltaic device and system technology has recently been completed by an industry supported task group. The task group was appointed by the National Fire Protection Association as an ad hoc Task Group for Article 690 - Solar Photovoltaic Systems. The task group was supported by the Department of Energy's National Photovoltaic Program, the Solar Energy Industry Association, and most importantly by all sectors of the photovoltaic industry.

Seven joint Task Group and SEIA Standards and Codes Technical Review Committee meetings served to unify the participants of the photovoltaic industry on code issues. Discussions, information exchange, and industry consensus also greatly clarified the needs and justifications for code changes. A number of the changes were needed because of advances in technology, such as the new AC photovoltaic module, and building-integrated applications. Changes were also written to provide clarifications of the current language and to ease some unnecessary requirements currently in the NEC.

The task group provided timely 1999 NEC related input by submitting 59 proposed photovoltaic system-related changes to the National Fire Protection Association. The work concentrated on industry-prioritized issues related to safety and performance. Changes on fire and personnel safety, system servicing, AC photovoltaic modules, integration of photovoltaics into building electrical systems, point-of-connection for building integrated photovoltaic systems, clarifications for hybrid system, batteries, and charge controller were proposed. Close coordination with Underwriters Laboratories (UL) and IEEE standards committees has been an important activity in this work.

Proposed Changes

Proposed changes covered the entire scope of Article 690. A large number of changes were made in the definition section that described new devices, tied the Sections of Article 690 to the remainder to the code, and provided consistency throughout Article 690. The definitions affected are listed in Table 1.

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Definition	Type of Change	Impact, Consequence or Description
AC Module (AC Photovoltaic Module):	New Definition	Allows AC module applications. Defines AC modules as a complete listed package for Section 690-6 (AC Modules).
Array	Minor Change	Removed the old reference to thermal controller.
Charge Controller:	New Definition	Defined the role of charge controller in PV systems.
Electric Production and Distribution System	New Definition	Defined a utility grid as one that is not controlled by the PV system. Needed to better differentiate hybrid systems.
Hybrid System	New Definition	Defined hybrid systems and energy sources in hybrid systems.
Interactive System	Change the Definition	Defined interactive system as tied to the utility grid.
Inverter	Change the Definition	Better defined charging functions associated with some inverters.
Inverter Input Circuit:	Minor Change	Defined inverter input circuit for both stand-alone and interactive inverters.
Inverter Output Circuit	Minor Change	Clarified definition
Module	Minor Change	Clarified definition and helped to differentiate AC modules.
Photovoltaic Output Circuit:	Minor Change	Changed to make language consistent.
Photovoltaic Source Circuit:	Minor Change	Changed to make language consistent.
Stand-Alone System:	Change	Clarified to remove tie to utility interactive systems.
System Voltage	New Definition	Added to provide consistency throughout the Article.

Table 1. List of proposed definition changes for 1999 Article 690, NEC

Other changes included new Sections in Article 690 and significant changes to existing language. The changes were based first on safety, then on photovoltaic system installation impacts, good engineering practice, interface with the utility, and lastly on system cost or performance.

A very significant proposal was the addition of Section 690-6 to provide circuit and labeling requirements for installation of the evolving AC module technology. Although just emerging as a new product, these devices will very likely find their way to hardware and department stores, architect's manuals, and builder's product lines by the time the 1999 NEC is issued. There have been more than 100 installed in the US already, and orders exist for almost 1000 more. This new section provides the necessary requirements for safe installation and connection of listed AC modules to the utility lines and to provide the rules for labeling AC photovoltaic modules.

The addition of Part I to deal with photovoltaic systems with dc voltages greater than 600 volts, along with the requirement that installations in single- and two-family homes be limited to 600 volts, gives valuable safety rules for photovoltaic installations. The addition clarifies the intent of system voltage calculations and requirements, and makes it perfectly clear that systems with maximum system voltages over 600 volts use a different set of rules.

Table 690-7 and the rules for applying the temperature correction for crystalline and multi-crystalline photovoltaic applications more accurately apply worst-case local temperature corrections to open-circuit voltage in those systems. The table addresses the photovoltaic technology that has the greatest temperature coefficient for open-circuit voltage and the temperature break points were carefully selected to match photovoltaic modules that were commercially available. Section 690-7(a) also gives instructions to refer to manufacturer specifications for when other than crystalline photovoltaic technologies are installed. The proposed table is reproduced here as Table 2.

Correction Factors for Crystalline and Multi-crystalline Silicon Modules		
Ambient Temp. °C	For ambient temperatures below 25°C (77°F), multiply the rated open-circuit voltage by the appropriate factor shown below	Approximate Ambient Temp. °F
25 to 10	1.06	77 to 50
9 to 0	1.10	49 to 32
-1 to -10	1.13	31 to 14
-11 to -20	1.17	13 to -4
-21 to -40	1.25	-5 to -40

Table 2. Proposed Table 690-7 Voltage Correction Factors for Crystalline and Multi-crystalline Silicon Modules.

The integration of the solar enhancement (125%) factor (currently a UL requirement) and the 80% derating factor for continuous current for photovoltaic array conductors and fuses has been needed for many years. There has been

much confusion in applying these factors in the past, but the proposed change for 1999 puts everything in the NEC and simplifies calculation requirements. The coordination with UL will remove the 125% requirement in their standard for listing modules.

A revised Section 690-5 provides much needed clarification for ground-fault protection of roof-mounted photovoltaic installations for fire protection. The revisions provide rules for the detection, interruption and indication of ground faults. Indication is very important, since ground-fault interruption of grounded photovoltaic sources involves disconnecting (or lifting) the grounded conductor or placing a high resistance in the ground path. The previous 1996 NEC gave no direction and the 1996 NEC handbook tried to address the issue but used the term "disable the array" which was a topic of serious debate, since the only way to truly disable an array is to block the sunlight. The revisions give rules for disconnecting the faulted photovoltaic source, lifting the ground connection and for indicating the condition of the system.

Two related proposed changes address the issue of connecting inverters to commercially available service entrance panels. They were written to clarify the rules for sizing circuit conductors and supplying power to service entrance hardware at lower than service panel rated currents. Relevant proposals for using the terminology "maximum system voltage" were also made to provide clarity and consistency.

A proposal was submitted to provide the necessary language in Section 690-64(b) to allow the ac connection of photovoltaic systems at the load side of the service disconnecting means or at any distribution equipment on the premises. This serves the practical side of photovoltaic systems since the arrays can be located on the roof of buildings and the service disconnecting means is usually at a lower level in an equipment room. This new language will better facilitate building integrated photovoltaic installations.

Deletion of the need to install photovoltaic systems in accordance with the provisions of Article 705 "Interconnected Electric Power Production Sources" clarifies photovoltaic system installation requirements. Photovoltaic systems and equipment often have characteristics that are distinctly different from the equipment such as uninterruptible power supplies and emergency generators addressed in Article 705. This proposal eliminates a cross reference in the NEC and allows Article 690 to stand on its own for photovoltaic installations.

Modification of the existing Figure 1 of Article 690 was needed to clarify the intent of the figure. Numerous installations have been plagued with uncertainty because designers have tried to use the figure for system design or because inspectors insist the system should look like the figure. The proposed new figure specifies that it is for component identification only and is purposely designed to indicate options only.

A proposal that was rejected by the code making panel for the 1999 NEC was to permit a single phase, 120 V inverter to supply power to a single phase 120/240V service entrance panel provided there were no multiwire branch circuits. There are estimated to be more than 50,000 such installations already, but no allowance is given in the existing code. The widespread multiwire branch circuits contains a common neutral conductor that may be overloaded when used with single 120V inverters. The task group will provide additional input to the code making panel for this and other proposals that need further clarification.

Summary

Publication of the 1999 National Electrical Code with a strong and well-developed Article 690 on photovoltaic power systems will represent a safety code that will enable future photovoltaic systems to be installed with well understood requirements. An enhanced common understanding among the manufacturers, designers, installers and inspectors will result from this work. Good installation practices required by the NEC will also improve long-term system performance and reliability. Improved system reliability will also be a natural improvement that results from writing and complying with the NEC. The installations will also be easier to inspect, and above all, will provide safety for the user.

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