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NATIONAL ELECTRICAL CODE CHANGES FOR 1996 AND USA PARTICIPATION IN INTERNATIONAL ENERGY AGENCY ACTIVITIES RELATED TO PHOTOVOLTAICS SAFETY AND GRID INTERCONNECTION*

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ABSTRACT: As photovoltaic (PV) systems gain more acceptance in utility-interactive applications throughout the world, many organizations are placing increasingly higher priorities on writing guidelines, codes and standards. These guidelines and codes are being written to improve safety, installation, acceptance, listing or certification of the PV components or systems. Sandia National Laboratories' PV System Applications Department is working closely with the PV industry to address issues that are associated with fire and personnel safety and with National Electrical Code (NEC) requirements. Additionally, the United States has agreed to participate in two of the International Energy Agency (IEA) Annexes (topical tasks) of the Implementing Agreement for a Cooperative Programme on Photovoltaic Power Systems. This paper describes events and activities associated with the NEC and the IEA that are being led by Sandia National Laboratories with broad participation by the US PV industry.

1. INTRODUCTION: The National Electrical Code (NEC) is the most used document that governs PV installations in the USA.(1) The International Electrotechnical Commission (IEC) is writing standards that are used throughout many of the European countries, and in whole or in part, in other countries worldwide. Some countries, such as Japan, have written country-specific guidelines and standards for installing and grid-interconnecting PV systems.(2) The International Energy Agency (IEA) has established the Implementing Agreement for a Cooperative Programme on Photovoltaic Power Systems that is an international collaborative effort to identify issues, to write guidelines and reports that address the technical issues, and to conduct collaborative PV research and development and PV system evaluations where appropriate.(3)

The Sandia directed NEC code work seeks strong industry participation through the Solar Energy Industries Association (SEIA) and through direct contact with the PV industry. The Southwest Technology Development Institute (SWTDI), through a contract with Sandia, also provides many code workshops to electrical inspectors and industry, prepares inputs to standards and code-related committees, reviews PV system designs with regard to code issues and continues to evolve a "Suggested Practices" manual for PV/NEC requirements.(4)

CMP#3 is the code making panel that is responsible for Article 690, the PV section of the NEC. SEIA sponsors active US industry membership on this panel to deal with modifications to Article 690 of the NEC. Additionally, Sandia provides an alternate member on CMP#3. A NEC Task Group, Article 690--Solar Photovoltaic Systems--was appointed by the National Fire Protection Agency (NFPA), as a result of a request from CMP#3, to address questions and to provide PV industry expertise to CMP#3 on PV components and system issues.

The IEA effort at Sandia includes support for Annex 1, titled Exchange and Dissemination of Information on Photovoltaic Power Systems, and Annex 5, titled Grid Interconnection of Building Integrated and Other Dispersed Photovoltaic Power Systems.(5,6) The expert representing the USA in Annex 1 is Charles Linderman of the Edison Electric Institute, and for Annex 5, Ward Bower of Sandia National Laboratories.

2. THE NEC BACKGROUND: The United States does not have one single guideline, code or standard by which photovoltaic (PV) systems may be connected to the utility grids, or for installations of stand-alone or PV hybrid

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systems. Many utilities that are active in a PV program write their own guideline for PV systems, and for other dispersed generation devices, for interconnections to their system. Where no such utility-specific document exists, a selection of a number of standards, guidelines, codes and local rules are used by installers, manufacturers and utilities to technically design, qualify and accept installations for interconnection to the utility grid. In general, stand-alone and hybrid systems must also meet either the local requirements or those of the NEC. The NEC is mandated by law in at least 40 states, and by most major cities. Modifications, adaptations, and local interpretations of the NEC are often used by municipalities and state jurisdictions.

The NEC was established in 1897. It was established by the NFPA to deal with the safe installation of nearly all electric power systems that are outside of the utility owned and operated generation or distribution network. Although the NEC now includes requirements for personnel safety (the requirements for ground fault circuit interrupters for example) its primary goal began as, and is still, fire safety. The NEC is an American National Standards Institute publication and is designated ANSI/NFPA 70, but is copyrighted by the NFPA.

Nearly all devices that have external electrical terminals that must be wired or connected to other powered or power supplying devices come under the auspices of the requirements established by the NEC. Motor-driven generators are covered, as are systems with operating voltages under 50 volts, emergency systems, and legally-required standby power systems. Self-contained systems with no external electrical connections, such as small PV-powered walk lights, do not generally fall under the auspices of the NEC.

Article 690--Solar Photovoltaic Systems--of the NEC covers PV power systems. It was added to the NEC in 1984, nearly ten years after the first terrestrial PV system was first connected to a utility grid. This was the first time PV systems were explicitly mentioned in the NEC. Areas concerning PV systems that are covered in Article 690 include: General, Circuit Requirements, Disconnecting Means, Wiring Methods, Grounding, Markings, Connection to Other Sources, and Storage Batteries. PV systems must meet the requirements of other Articles of the NEC where requirements are not specifically addressed in Article 690. Article 690 was revised and expanded in the 1987, 1990, 1993, and 1996 code cycles.

There is no categorization for PV system configurations, rated outputs, end use or complexity in Article 690. Both ac and dc systems are included in Article 690. Residential-size PV systems, for ac loads, are limited to single-phase installations. Intermediate- and central station-size systems may range into the multi-megawatt size, are generally three-phase, and are covered by this same article. Article 690 of the NEC limited the dc voltage for PV systems to 600 volts through the 1993 edition, but removing this limitation for all but single- and two-family dwellings has been accepted by CMP#3 for potential change in the 1996 NEC. Article 690 does not include any requirements for system or component performance, reliability, maintenance, life expectancy or costs. The NEC does require that listed or certified hardware be used for all installations if that listed hardware is commercially available.

3. SUMMARY OF CMP#3 ACTIONS ON PROPOSALS FOR THE 1996 NEC: The PV-related changes to Article 690 for the 1996 NEC that were publically submitted, voted upon and enacted included twenty-six proposals. Nineteen of those proposals submitted in November 1993 were accepted, accepted in principle, or accepted in principle in part by CMP#3, the NEC panel responsible for Article 690. The following summarizes the twenty-six submittals:

4 definitions (all accepted)
1 figure modification (Figure 1) (accepted)
5 clarifications (text changes) (4 accepted)
3 regarding disconnects and protection (all rejected)
6 regarding system rating (6 accepted)
4 regarding grounding (all accepted)
1 regarding service entrance requirements (rejected)
5 regarding cables and cords (4 accepted, 1 rejected)
2 regarding marking and labels (all accepted)
3 regarding component requirements (1 accepted, 2 rejected)

Only seven of the proposals introduced in November 1993 were rejected by CMP#3, and four of those proposals were referred to the Task Group for Article 690,--Solar Photovoltaic Systems-- for recommendations, study, and action. The four direct referrals to the NEC Task Group included PV circuits above 600 volts, concerns on

electroendosmosis of certain poly-vinyl-chloride insulation (UF cable) used in PV dc circuits, concerns regarding classification of storage battery areas, and concerns about NiCad batteries in PV systems without charge controllers. The greater than 600 volts for other than single-and two-family dwellings, electroendosmosis, and charge controller proposals were all subsequently accepted because of the Task Group substantiation and clarification.

4. TASK GROUP FOR ARTICLE 690, --SOLAR PHOTOVOLTAIC SYSTEMS--: The formation of this Task Group for Article 690--Solar Photovoltaic Systems--was requested by the chairman of CMP#3 and approved by the NEC correlating committee, to provide PV industry expertise to CMP#3 for Article 690. The scope of work for NEC Task Group is reproduced here. *"Review ANSI/NFPA 70, NEC Article 690 including Part A-General, Part B-Circuit Requirements, Part C-Disconnecting Means, Part D-Wiring Methods, Part E-Grounding, Part F-Markings, Part G-Connection to Other Sources, Part H-Storage Batteries. Make recommendations to CMP#3 to clarify the intent of the Article relative to the present utilization practices and applications."*

One major goal of the Task Group is to determine if the scope of Article 690 is sufficient for today's PV technology, or if Article 690 needs to be rewritten to provide categorization of PV systems. A slight majority of Task Group membership is currently satisfied that the scope of Article 690 is sufficient for today's PV technology and that a rewrite of Article 690 is not needed. A majority of the Task Group also thinks that categorization of PV systems in Article 690 is not needed. This Task group is also required to provide substantiation and study of issues that need clarification or expansion in Article 690.

The NEC Task Group membership was chosen by CMP#3 to include knowledgeable industry and other participants that could provide a two-way communications interface with industry. Table 1 lists the Task Group members. Contacting any member of the Task Group with code-related questions or suggestions is encouraged as a method for industry participation and input into the NEC.

4.1 Technical Review Committee for Standards and Codes: A major goal of the Sandia National Laboratories' National Electrical Code (NEC) activity with industry is to work with and inform them about code-related activities and issues. SEIA is the designated conduit for all correspondence, with peer review by Sandia and SWTDI. As part of this activity, SEIA provides a Vice Chairman of the NEC Task Group for Article 690,--Solar Photovoltaics Systems--. Additional technical support and PV industry interface that is provided by the SEIA Technical Review Committee for Codes and Standards (TRC) consists of timely industry contacts through telephone, FAX, e-mail, and published articles. Tentatively scheduled meetings for the NEC Task Group, jointly meeting with the TRC, for the 1999 NEC cycle include:

1) A module wiring subgroup meeting in conjunction with Standards and Codes Forum at Golden, CO on June 28, 1995.
2) A TRC and Task Group meeting in conjunction with the American Solar Energy Society (ASES) conference at Minneapolis on July 14-15, 1995. 3) A TRC and Task Group meeting in November 1995.
4) A TRC and Task Group meeting in conjunction with the annual Soltech96 to be held in the February-March 1996 time frame.
5) A TRC and Task Group meeting in conjunction with the IEEE PV Specialists Conference in June or July 1996.
6) A TRC and Task Group meeting at Underwriters

TABLE 1. NEC TASK GROUP MEMBERSHIP

Chairman	Ward Bower	Sandia National Laboratories	Ph. 505-844-5206	FAX 505-844-6541
Vice Chair	David Meakin	SEIA	Ph. 202-383-2617	FAX 202-383-2670
Secretary	John Wiles	SWTDI	Ph. 505-646-6105	FAX 505-646-3841
Member	Hans Meyer	Omnion Power Engineering Corporation	Ph. 414-642-7200	FAX 414-642-7760
Member	Robert Wills	Skyline Engineering	Ph. 603-878-1600	FAX 603-867-4643
Member	Laxmi Mrig	National Renewable Energy Lab (NREL)	Ph. 303-275-3778	FAX 303-275-3881

TABLE 2. SCHEDULE OF 1999 CODE CYCLE ACTIVITY

Date	Scheduled Code Cycle Activity (1999 Edition)
11/8/1996	Proposals for 1999 NEC must be submitted to NFPA
Jan. 1997	Code-making panels meet, vote and comment on all proposals.
May 1997	NEC Correlating Committee meets to provide input to Committee Report on Proposals (NEC-ROP). NFPA Annual Meeting follows.
Jun. 1997	NEC-ROP is sent to the mailing house. Document includes all proposals, panel actions, votes, and comments.
10/24/97	All public comments on ROP are due to the NFPA.
Nov. 1997	NPFA Meeting Fall Meeting.
Dec. 1997	Code-making panels meet to respond & vote on public comments submitted in response to ROP.
Mar 1998	Correlating Committee meets and reviews all comments and CMP panel actions.
Apr. 1998	Report on Comments (ROC) sent to mailing house. This includes all proposals accepted by the CMPs and the Correlating Committee.
May 1998	NFPA Annual Meeting takes place for final public comment and final voting to adopt 1999 NEC.
Jul. 1998	NEC 1999 will be published.

Laboratory in Northbrook, IL in October 1996 to finalize submittals for the 1999 NEC.

Action items established for the 1999 NEC cycle include the AC PV module and point of connection issues, PV module wiring, grounding and ground fault PV array disable, charge controllers, batteries in PV systems, and continued analysis of greater than 600 volt issues. Each of the meetings requires that attendees provide advanced preparation of materials, survey responses, and substantiating information pertaining to issues to be resolved. All members of the PV and balance-of-system industry are invited to attend these meetings. Most of the Task Group meetings are held in conjunction with other PV-related conferences in an attempt to reach as much of the industry as possible.

4.2. 1999 NEC Code Cycle Sequence: The NEC has a well-established schedule and procedure to allow for input for revisions and expansion of the code, as technology and requirements change. The NEC is reviewed every three years in what is termed a code cycle. The procedures in the cycle provide for a democratic process that encourages and includes public inputs from installers, inspectors, concerned organizations and individuals, as well as all associated industry. Table 2 shows the approximate time for scheduled events that will be part of the process by which the NEC for 1999 will be modified. The shaded dates are public input deadlines.

5. INTERNATIONAL ENERGY AGENCY ACTIVITIES: The US government participates in several (wind, PV, Solar Heating and Cooling) IEA collaborative, developing-technology programs that were approved through diplomatic channels and have potential value to US industry. Sandia's Photovoltaic System Applications Department, in cooperation with the US DOE is supporting a five-year IEA Implementing Agreement for a Cooperative Programme on Photovoltaic Power Systems. The effort includes support for two of the annexes outlined in the IEA Implementing Agreement. Annex 1, titled Exchange and Dissemination of Information on Photovoltaic Power Systems, and Annex 5, titled Grid Interconnection of Building Integrated and Other Dispersed Photovoltaic Power Systems, are supported. Seventeen countries, including the USA, are now collaborating to address major technical and informational barriers that are limiting the rate at which PV advances into the utility markets.

The Annexes that the USA is not participating in include Annex 2, titled Operational Performance and Design of Photovoltaic Systems and Subsystems, Annex 3, titled Use of Photovoltaic Systems in Stand-alone and Island

Applications, Annex 4, titled Modeling of Distributed Photovoltaic Power Generation in Support of the Grid, and Annex 6, titled Design and Operation of Modular Photovoltaic Plants for Large-scale Power Generation. Table 3 shows the country membership status of the IEA Implementing Agreement for a Cooperative Programme on Photovoltaic Power Systems.

5.1 IEA Annex 1 Activities and Status: Under Annex 1 of this IEA program, expected results include a bi-annual survey of PV power applications with particular emphasis on the diffusion in successful niche markets, semiannual newsletters, an executive conference on PV power systems and major policy issues, and special workshops on critical aspects of PV power systems. Two newsletters have been published and are titled "PV Power; Newsletter of the IEA Photovoltaic Power Systems Programme."(7) The first bi-annual survey has been completed and is titled "Photovoltaic Power Systems in Selected IEA Member Countries" and will be published by IEA.(8) The results of this work are intended for use by utility executives, senior government officials and local regional regulators and developers of PV hardware and systems. The Executive Conferences aid the dissemination of information for the IEA membership , industry and utilities.

Previously, the first IEA Executive Conference on Photovoltaic Systems for Electric Utility Applications took place in Taormina, Italy in December 1990. That conference had a positive impact on the business development of PV in the utility sectors of the IEA member countries, including the United States, and eventually led to the establishment of the IEA Implementing Agreement on PV Power Systems

The second IEA executive conference, the International Executive Conference on Strategic Photovoltaic Business Opportunities for Utilities, henceforth called the International Executive Conference, will be co-hosted by Idaho Power Company, Edison Electric Institute (EEI), and supported by the State of Idaho, the Idaho Public Utilities Commission (IPUC), and US Department of Energy (US DOE). This conference will take place during September 17-20, 1995 at Sun Valley, Idaho. It is expected that the

TABLE 3. COUNTRY MEMBERSHIP IN IEA IMPLEMENTING AGREEMENT ON PV POWER SYSTEMS (6)

Country	Annex 1	Annex 2	Annex 3	Annex 4	Annex 5	Annex 6
Austria	O	O			O	
Canada	O	✓	O		✓	
Denmark	O				O	
European Union	O					
Finland	O		O		✓	
France	O	O	✱		✓	
Germany	O	✱	O		O	✓
Israel	O	O			O	O
Italy	✱	O	O	✓	O	✱
Japan	O	O	O		✱	O
Korea	O		O			
Netherlands	O	O	O		O	
Portugal	O	✓	O	✓	O	O
Sweden	O	✓				
Switzerland	O	O			O	
Turkey	O					
United Kingdom	O	✓	O		O	O
USA	O				O	

✱ Operating Agent O Country Participation ✓ Participation Under Consideration

conference will be attended by 150 to 200 participants. The conference will invite high-level industry and utility executives, distinguished dignitaries, and government officials from at least 20 different countries and should allow timely policy information exchange that will directly and positively impact the US electric utility industry and the US PV industry.

5.2 IEA Annex 5 Activities and Status: The Annex 5 objectives are to develop and verify technical requirements that can serve as technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these guidelines will include safety and reliability issues as related to grid-interconnection, with cost integrated as an issue. Systems considered under Annex 5 include grid-connected systems rated under 50 kW. Expected results include a survey report on the operational experiences in each of the member countries with roof-mounted and dispersed PV systems connected to the utility grid, publication of technical guidelines and specifications for dispersed grid-connected PV systems, and performance evaluation procedures and guidelines that are confirmed through demonstrations at several member country evaluation facilities. Each member country has suggested sites for collaborative evaluations to take place. The Rokko Island test facility has been selected by Japan, the Operating Agent for Annex 5.(9) The US is considering using Sandia National Laboratories, the Florida Solar Energy Center (FSEC) or others. The results of Annex 5 work are intended to be used by engineers within the PV industry and by utility transmission and distribution engineers.

Annex 5 is divided into four subtasks. Subtask 10 participants review previously installed PV systems and experiences, local regulations, existing standards, codes and guidelines, and utility characteristics on a country-by-country basis. Subtask 10 surveys and system analysis will be published and subsequently used in Subtask 20. Subtask 20 participants identify the pertinent issues associated with grid-connected PV systems, prioritize them, identify needed studies, and identify needed evaluations and demonstrations that may be performed in a collaborative manner in Annex 5. The Subtask 20 team has already performed a country-by-country survey of the issues and has categorized those issues according to the sum of the individual country's prioritization and according to whether additional work by Annex 5 would be appropriate. Table 4 lists the total priority scores (Σ) from reporting member countries, where the lowest score is the highest priority. The Annex 5 action categories are represented by shading on the table. The unshaded blocks represent the subjects for Subtask 30 consideration. Subtask 30 teams will perform evaluations through demonstrations of PV systems at selected member country test sites, and will use the requirements and issues identified in Subtask 20 as guidelines for the work. Subtask 40 teams will summarize the results of the Annex 5 work and will produce a general report that includes contributions from all member countries of Annex 5.

5.3 IEA Annex 5 Schedule for the Coming Year: Possible demonstration sites in each country have been discussed and will be selected within the next year. The next Annex 5 meeting is tentatively planned in Freiburg, Germany on September 25-26, 1995 and will coincide with an IEA Heating and Cooling Task 16 meeting.(10,11) Task 16 is nearing completion and has extensively analyzed and documented building-integrated PV issues that may be transferred to the IEA Photovoltaic Power Systems Implementing Agreement, and have already been used to guide Subtask 20 work. Topics of discussion at this meeting will include work plans for evaluating each of the key issues identified in Subtask 20, a survey of utility control plans for PV installations on a country-by-country basis, module integrated converter (MIC) progress on a country-by-county basis, and identification of available hardware for Subtask 30 work. Members of US industry are welcome to attend the meeting but should make arrangements by contacting Ward Bower so that IEA approval can be obtained.

6. SUMMARY: The changes for the 1996 NEC were discussed and the plans for both the NEC Task Group and the SEIA TRC for Codes and Standards were reviewed with schedules and activities outlines. The IEA activities were discussed with schedules and activities presented. The US PV industry is encouraged to participate in these activities and any questions or suggestions are welcomed.

7. REFERENCES:

(1) National Electrical Code - 1993, ANSI/NFPA-70, Published by the National Fire Protection Association, Quincy, MA, 1992

TABLE 4. PERCEIVED IMPORTANCE FOR FURTHER STUDY BY MEMBER COUNTRIES

No	Subject	Σ
1.1	Isolation Transformer	24
1.2	DC Voltage Limit	22
1.3	External Disconnector	23
2.1	DC Injection	23
2.2	EMI of the Inverter (Array)	20
2.3	Overvoltage Devices (Surge Protection)	16
2.4	Grounding	13
2.5	Ground Fault Detector	16
2.6	Separation of Protective Devices	17
2.7	Certification (Listing)	19
2.8	Reliability	21
2.9	Module Integrated Converter (MIC) or (AC Module)	14
2.10	DC Busbar/System Switching	22
3.1	Islanding	14
3.2	Safety of Workman	16
3.3.1	Utility Control	24
3.3.2	Negative Power Flow	22
3.3.3	Power Fluctuations	18
3.3.4	Growth in Fault Currents (Reverse Contrib.)	23
3.3.5	Voltage Profile	23
3.3.6	Power Rating of Xformers	20
3.3.7	Allowable Generation Level	24
3.3.8	AC Voltage Drops	24
3.3.9	Fault Infeed and Unselective Protection	19
3.4	Customer Service	26
3.5	Harmonics	13
3.6	Reclosing	21
3.7	Multiple Inverters	2*

Should be pursued by Annex 5
Examine on topic by topic basis
Should not be pursued by Annex 5

(2) Outline of Official Guideline for Utility Interconnection in Japan, Prepared by CRIEPI, Tokyo, Japan, 1993

(3) Bower, W.I., Durand, S.J., Wiles, J.C., "Safety, Performance and Reliability of Photovoltaic Systems," Tutorial - First World Conference on Photovoltaic Energy Conversion, Waikoloa, HI, December 5-9, 1995

(4) Wiles, J.C., Photovoltaic Power Systems and the National Electrical Code - Suggested Practices, Prepared by the Southwest Technology Development Institute, Las Cruces, NM, Jun. 1994

(5) International Energy Agency Implementing Agreement on Photovoltaic Power Systems, 1993 Annual Report, Edited by Eva-Elena Bruno, ENEL S.p.A R&D Department, Rome, Italy, Jan. 1994

(6) International Energy Agency Implementing Agreement on Photovoltaic Power Systems, 1994 Annual Report, Edited by Eva-Elena Bruno, ENEL S.p.A R&D Department, Rome, Italy, Jan. 1995

(7) PV Power - Newsletter of the IEA Photovoltaic Power System Programme, Number 2, Written by IT Power, Courtesy of NOVEM, Netherlands, March 1995

(8) Morse, F.H., Photovoltaic Power Systems in Selected IEA Member Countries, to be published mid-1995

(9) Kitamura, A., Takigawa, K., Okamoto, M., Kobayashi, H., Hotta, K., Ariga, Y., "Islanding Prevention Measures: Demonstration Testing at Rokko Test Center for Advanced Energy," Proceedings of the 23rd IEEE PV Specialist Conference, Louisville, KY, May 1993

(10) International Energy Agency Solar Heating and Cooling Program, Program Description and Publications, International Energy Agency, 1993

(11) Photovoltaics in Buildings, The IEA-SHCP-T16 Task Brochure, Published by the International Energy Agency, 1993