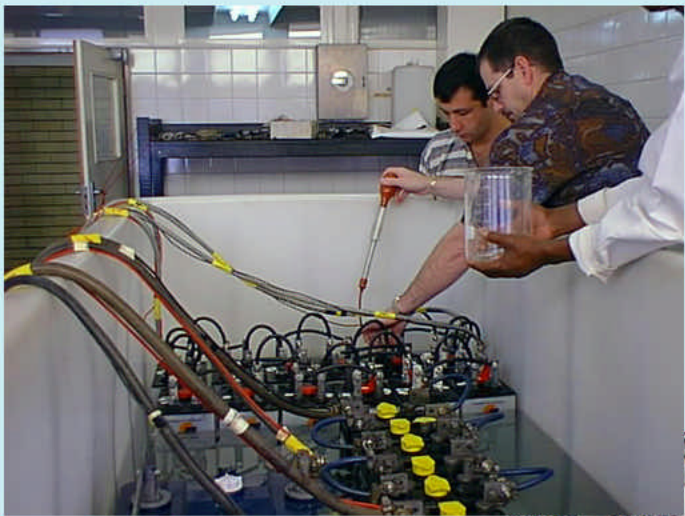
IEA INTERNATIONAL ENERGY AGENCY

Survey of National and International Standards, Guidelines & QA Proceedures for Stand-Alone PV Systems 2nd Edition



PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA PVPS T3-07:2004

SURVEY OF NATIONAL AND INTERNATIONAL STANDARDS, GUIDELINES AND QUALITY ASSURANCE PROCEDURES FOR STAND-ALONE PV SYSTEMS

Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 24 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems (PVPS) Programme is one of the collaborative R&D agreements established within the IEA and, since 1993, its Participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently nine tasks have been established. The twenty-one members of the PVPS Programme are:

Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

This International Technical Report has been prepared under the supervision of PVPS Task 3 by:

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in co-operation with experts of the following countries: Australia, Canada, France, Germany, Japan, Netherlands, Norway, Portugal, Spain, Sweden and Switzerland.

The report expresses, as nearly as possible, a consensus of opinion of the Task 3 experts on the subjects dealt with.

SHORT ABSTRACT AND KEYWORDS

The International Energy Agency (IEA) is an autonomous body within the Organisation for Economic Co-operation and Development (OECD) formed to encourage co-operative ventures among the 24 member nations. The Agency's efforts include efforts into the research, development and demonstration of new energy technologies.

The Implementing Agreement on Photovoltaic Power Systems was initiated to assist in the development of the world photovoltaic market. The agreement is divided into seven tasks, of which Task 3 deals with Photovoltaic Power Systems in Stand-alone and Island Applications. Within this Task, Quality Assurance of PV systems is considered of special interest.

In an effort to assist the implementation of Quality Assurance for stand-alone and island photovoltaic power systems in both IEA member and non-member countries, it is intended that Task 3 Experts should establish communication with the relevant standards and quality assurance (QA) organisations. It is hoped that this dialogue will assist in the development of appropriate guidelines for QA procedures.

Prior to the start of this dialogue, however, an understanding of the current status of National and International Standards needs to be formulated. In order to gain a complete picture of the present status of national and international guidelines and QA procedures, the Task 3 Experts each completed a survey on current guidelines in their respective countries. In addition, a comprehensive study of international guidelines has also been undertaken by IT Power. The results of these surveys form the basis for this document.

Keywords: national and international standards, QA procedures, guidelines, stand-alone PV systems.

ACKNOWLEDGEMENT

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Cover Photograph: Solar Home Systems for sale in Tibet. Photograph courtesy of IT Power.

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EXECUTIVE SUMMARY

Task 3 of the Photovoltaic Power Systems Programme, *Stand-alone and Island Applications,* is focusing efforts on Quality Assurance (QA) aspects of stand-alone PV systems. As a starting point for this work, a review of existing programmes of standardisation and QA for PV was necessary, in order to gain an overall picture of the work presently being done and so identify ways in which Task 3 can best make a contribution to this work.

This survey describes the role of international and national standardisation and QA organisations, and the work which they are conducting to provide guidelines for the application of quality stand-alone PV (SAPV) systems. The document undertakes a review of existing standards and guidelines, and describes in brief any relevant specifications, reports and Best Practices which are relevant to the subject of QA procedures for SAPV systems. This document has been made available on the internet.

Most of the standards published to date concern PV modules and their measurement methods. However in recent years, major international standards committees, such as IEC and CENELEC, have started work on standards for PV systems and the electronic components required for their control (BOS components). In addition, the PV GAP was initiated by the PV industry to address the problem of PV system quality. This organisation has published a number of global interim standards to attempt to accelerate the supply and installation of quality systems.

A number of other organisations are also active in this field, with the aim of improving the quality of installed SAPV systems. These include the World Bank, the UNDP, GTZ, and also a number of national programmes which have been started to address the lack of globally accepted standards, test procedures and laboratories for SAPV systems. This survey reviews the progress made by these organisations.

The survey identifies areas where there are insufficient, or no guidelines, and suggests a Task 3 plan of action to fill some of these gaps. The document in itself identifies all the existing widely used guidelines for SAPV systems and provides a useful resource which describes the current status of existing standards and QA programmes in this field.

1. INTRODUCTION

The potential market for stand-alone PV systems is very large. Stand-alone PV systems are usually installed where it is more economic to use PV than any other form of power supply. A large proportion of this market is in developing countries, but there is also a demand for stand-alone PV in industrialised countries. Typical developing country applications are solar home systems (typically lighting systems, often with the option to connect a radio, television, etc), applications in health care, and PV pumping.

There is also a market for stand-alone PV systems to power professional applications, known as 'service applications'. This market mainly consists of niche applications for remote power supply. It is a fully commercial market operating without any subsidies. Examples of applications are: telemetry systems for water or gas utilities; marine navigation aids; telecommunication systems, and certain applications in the transport sector.

It is widely accepted that the continued development of markets for stand-alone PV systems is greatly hindered by the absence or limitations of national and international standards and QA procedures. This is illustrated by the fact that the quality of PV systems and components installed and sold to date varies considerably. As a result of the marketing of poor quality systems in the past, the markets of today are impeded.

This document reviews current national and international standards, guidelines and QA procedures in order to assess the areas in which these guidelines are lacking. It is intended to provide a starting point from which a means of providing Quality Assurance for stand-alone PV systems can be devised.

The development of standards for stand-alone PV systems takes place within IEC and CENELEC, with several international standards published and many more under development. However, at present these standards mainly address PV modules, batteries and lights. In the areas of charge controllers, inverters and stand-alone PV systems as a whole, work on several standards projects is currently in process.

The issue of quality assurance for PV systems is extremely complex, not least because of the many different players involved in the design, supply, installation, operation and maintenance of a PV system. To guarantee the quality level of an installed system each party must have a contractual responsibility: from the identification of energy-service requirements, through to installation, operation and maintenance activities.

Each stage in the life cycle of a PV system must be considered as a potential source of system failure. However, evaluation of previous projects has shown that most of the maintenance and repair requirements result from failures in the specification, design, and installation processes.

Systematic quality assurance of an SAPV project must include several areas:

- definition of component and system standards
- definition of laboratory tests
- testing of product samples in accredited laboratories
- quality of system design
- definition of installation procedures
- installation by trained technicians
- on-site quality control / acceptance testing / commissioning of systems
- provision of adequate warranties / performance guarantees
- O&M schedules and other documentation to be provided, e.g. user manual
- user satisfaction

The purpose of this document is to review the available standards and documented QA procedures, to identify areas where there are no guidelines, and to make proposals for work to be carried out to fill those areas.

2. STANDARDS ORGANISATIONS

2.1. International Standards Organisations and Regulatory Bodies

There are now significant programmes on PV systems in the IEC (International Electrotechnical Commission), and in the European Standards body CENELEC. Standards for stand-alone PV Systems are currently being developed by both organisations. These organisations are outlined here. In addition, PV GAP has been initiated in recent years primarily to address quality issues of PV systems. One of its activities is to propose draft recommended standards which can be used until formal standards are published. PV GAP is described in Section 4.

2.1.1. International Electrotechnical Commission (IEC)

The IEC established a Technical Committee (TC82): Solar Photovoltaic Energy Systems, in 1981. Its purpose is to prepare international performance and safety standards for PV cells, modules and systems.

There has been a long period of international R&D which has led to IEC Standards for all aspects of silicon cells and modules and, more recently, draft standards for PV systems and BOS components.

TC 82 is divided into 6 Working Groups (WG), as detailed below:

Working Group 1: Glossary

Working Group 2: Modules, non-concentrating

Working Group 3: Systems

Working Group 4: PV energy storage systems

Working Group 6: Balance-of-system components

Working Group 7: Concentrator modules

Working Group 5 (Quality and certification) was disbanded at the end of 2003, after establishing a path for conformity assessment by the IECEE.

There is also a Joint Working Group with the task to prepare guidelines for decentralised rural electrification projects in developing countries.

2.1.2. European Committee for Electrotechnical Standardisation CENELEC

In 1995 the EU mandated CENELEC (the European standardisation body for electrical standards) to establish its own committee to prepare European PV standards. A CENELEC Task Force (BTTF-86-2) was established in 1996 to work on PV standards. This Task Force was later changed into a Technical Committee (CLC/TC 82).

There are three working groups:

WG1 Cells and modules

WG2 Inverters and grid connection

WG3 BIPV (Building-integrated PV)

The standard making process is similar to the IEC, with a draft being circulated for comment first, and a second time for a final vote. A number of IEC Standards have been adopted as CENELEC Standards with identical numbers (i.e. IEC 6xxxx is numbered EN 6xxxx).

2.1.3. Other international bodies which issue standards or codes of practice relevant to stand-alone PV

Several other bodies issue standards, guidelines or codes of practice which are of interest or relevance to stand-alone PV. The following list is not exhaustive.

The ISO (International Organisation for Standardisation) issues international standards in areas other than electrical and electronic engineering. For example, ISO Standards relevant for PV have been issued for glazing materials for use in buildings. In addition ISO Guides 25 and 62 have direct relevance to testing laboratories and accreditation. Lastly, the ISO 9000 series are standards for the quality management of organisations.

Within Europe, CEN (Comité Européen de Normalisation) deals with standards in areas other than electrical and electronic engineering.

The International Telecommunication Union (ITU) is an international organisation within which governments and the private sector co-ordinate global telecom networks and services. Its headquarters are in Geneva, Switzerland. The ITU is the leading publisher of telecommunication technology, regulatory and standards information.

The ITU-T Recommendations developed by the Telecommunication Standardisation Sector (formerly CCITT) constitute the basis for international telecommunication standards. These are final results of studies on technical, operating and tariff issues with the objective of standardising telecommunications on a world-wide basis, including interconnection of radio systems in public telecommunication networks and on the performance required for these interconnections.

ETSI, the European Telecommunications Standards Institution, deals with telecommunications standards on a European level.

The International Commission on Illumination, or CIE (Commission Internationale de L'éclairage), publishes information on all aspects of lighting.

2.2. National Standards Organisations and Regulatory Bodies

This section outlines the standards organisations in the participating IEA PVPS Task 3 countries. It also includes the USA for completeness. It gives a brief overview of the respective standards bodies, and details any specific activities related to stand-alone PV.

2.2.1. Australia

2.2.1.1. Standards Australia

In Australia, most Standards are published by Standards Australia. Standards Australia is the trading name of Standards Australia International Limited, a company limited by guarantee. It is an independent, non-government organisation. However, through a Memorandum of Understanding it is recognised by the Commonwealth Government as the most important non-government standards body in Australia, and represents Australia on the two international standards organisations, ISO and IEC. Its primary role is to prepare standards through an open process of consultation and consensus in which all interested parties from a variety of industries are invited to participate.

Standards Australia represents Australia on the two major international standardising bodies, the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC). It co-ordinates the attendance of Australian experts at international meetings, and participates extensively in the preparation of a wide range of international standards. It is active within the international standardisation movement and a number of senior management team members hold voluntary offices on international standards bodies.

As part of the Closer Economic Relations agreement, Standards Australia maintains strong links with Standards New Zealand, with whom it has a formal agreement for preparing and publishing joint standards where appropriate. It is a founding member of the Pacific Area Standards Congress (PASC), and it also co-operates closely with the Australian government in the standards and conformance activities of APEC and ASEAN-CER.

A number of Australian standards related to stand-alone PV have been published or drafted. These are discussed in Section 3, and listed in Annexes 1 and 2.

2.2.2. Canada

2.2.2.1. Canadian Standards Association (CSA)

CSA is an independent, not-for-profit organisation supported by more than 8,000 volunteers and members. The Canadian Electrical Code (CEC) is published every four years by CSA International. It consists of three parts:

Part I: Installation instructions

Part II: Equipment certification

Part III: Outdoor wiring

The CEC must be adopted by provinces and territories (and sometimes power companies) to stand as a law. Some will adopt it integrally, others will amend a few articles.

Introduction of PV in the CEC is relatively new. Section 50 - "Solar Photovoltaic Systems" of the CEC Part I was introduced in 1994. Revisions have been made in 1998-1999 and an updated issue is expected for 2002. This section covers rating of equipment, wiring methods, disconnecting means, marking, etc. of a safe PV system; it does not deal with issues related to performance.

As far as PV equipment certification is concerned (CEC Part II), Canada does not have any specific standards. General requirements for PV power conditioning equipment are covered in C22.2 No. 107.1-95 - General Use Power Supplies (which also covers stand-alone inverters). An addition to 107.1 is currently being drafted to cover utility-interconnected inverters, charge controllers and PV systems in general.

This is due to be published in 2001 / 2002.

2.2.2.2. Standards Council of Canada

The Standards Council has the mandate to co-ordinate and oversee the efforts of the National Standards System, which includes organisations (CSA, ULC etc.) and individuals involved in voluntary standards development, promotion and implementation in Canada.

2.2.3. France

2.2.3.1. Union Technique de l'Electricité et de la Communication (UTE)

UTE is the French organisation working on standardisation relating to equipment, installations and services in the electrotechnical sector. UTE is responsible for establishing, publishing and circulating standards, guides, manuals and technical documentation within this field of activity and holds all related patent rights.

UTE takes an active part in international and European standardisation work and prepares the French views on these bodies.

2.2.3.2. Association Française de Normalisation (AFNOR)

AFNOR is a state-approved organisation, placed under the supervision of the French Ministry for Industry. Its aims are :

- to pilot and co-ordinate the preparation of standards,
- to represent French interests within all standardisation bodies,
- to approve standards,
- to promote and facilitate the use of standards,
- to develop NF certification and products, services and systems certification.

2.2.4. Germany

2.2.4.1. Deutsches Institut für Normung e.V. (DIN)

DIN is a registered organisation with its headquarters in Berlin (DIN German Institute for Standardisation, founded in 1917). DIN standards serve the rationalisation, guarantee of quality standards, science, security, ecology, administration, and the public.

The specification work is done in 4 600 working committees with 28 500 external experts. Everybody can comment on specification drafts. DIN assures the formulation of the DIN specifications can be taken into consideration in the legislation as a description of technical facts. It is the authorised national representative in the committees of the international and European organisations for specification.

2.2.4.2. Deutsche Elektrotechnische Kommission im DIN und VDE (DKE) and Verband der Elektrotechnik, Elektronik & Informationstechnik e.V. (VDE)

DKE is the organisation responsible for the elaboration of standards and safety specifications covering the whole area of electrical engineering. It constitutes a joint organisation of the German Institute for Standardisation (DIN, Deutsches Institut für Normung e.V.) and the Association for Electrical, Electronic & Information Technologies (VDE, Verband der Elektrotechnik, Elektronik & Informationstechnik e.V.). The juridical responsibility for running the DKE belongs to the VDE.

The DKE represents and safeguards German interests within International and European standardisation organisations, such as IEC, CENELEC and ETSI.

The results of DKE standardisation are harmonised with European and International standards as far as possible and are included in the DIN standards collection as German standards. They are provided with a VDE classification in the VDE Specifications Code of Safety Standards as VDE specifications at the same time, if they concern safety regulations.

2.2.5. Japan

2.2.5.1. Japan Industrial Standards Committee (JISC)

JIS are voluntary national standards which are authorised by the Industrial Standardisation Law. The Japanese Industrial Standards Committee (JISC), based in the Standards Department, Agency of Industrial Science and Technology, Ministry of International Trade and Industry, plays a central role in establishing JIS.

The first JIS on PV systems was established in 1989. Since then, very comprehensive PV system standards have been developed in Japan. In 1993, the JIS on ‘General rules for stand alone PV power generating system’ (JIS C 8905) was published.

Annex 3 shows a listing of all JISC PV standards, with their relationship to IEC standards.

2.2.6. The Netherlands

There are no specific national PV standards; IEC standards apply instead. Two closely co-operating organisations are responsible for standards development in the Netherlands.

2.2.6.1. Nederlands Normalisatie-instituut (NNI)

The Nederlands Normalisatie-instituut (NNI or NEN) is the national standardisation body for the Netherlands. It assists and facilitates in the formulation of national standards. NNI is a private, non-profit foundation which co-operates closely with the Nederlands Elektrotechnisch Comité (NEC). Standardisation activities in all areas except the electrotechnical field are conducted by NNI. They also co-ordinate consumer interests and standardisation of companies.

2.2.6.2. Nederlands Elektrotechnisch Comité (NEC)

The Nederlands Electrotechnisch Comité (NEC) is a committee responsible for standardisation in the areas of electrical technology, information technology and telecommunications. It was established in 1911 as a foundation to contribute to national and international standardisation. To attain its objectives, NEC contributes to the global standardisation efforts in the IEC and, where relevant, in ISO. At the European level it contributes to the European Committee for Electrotechnical Standardisation (CENELEC) and the European Committee for Standardisation (CEN).

Standardisation in the electrotechnical and information technology fields is directed mainly at safety, health, quality and support of international exchange of goods and services.

Within a number of different standards committees, discussions take place between stakeholders such as: the state; industry; electricity utilities; software suppliers; education, research and certification organisations; installers; large electricity consumers, and users of electrotechnical products and information technology. The main objective of the NEC standards committees is to represent the interests of the Netherlands in IEC, ISO, CENELEC and CEN.

Draft standards are first made publicly available when they are circulated for comment to interested parties. Members and non-members of the committee can provide comments during this period.

Standards are produced on a voluntary basis. Their acceptation and application depends on:

- Dutch or European regulations;
- References in contracts;
- The speed with which the standard was approved;
- The needs of product suppliers and purchasers.

2.2.7. Norway

There is no official Norwegian standard for PV systems. This is because there are few suppliers / manufacturers, little interest from the authorities, and the fact that about 95 % of all installed PV systems have voltages of less than 48 V.

2.2.7.1. Standard Norge (SN)

A reorganisation in the standardisation system in Norway has resulted in establishing a new organisation, Standard Norge (Standards Norway), in November 2003. SN took over standardisation activities from the Norwegian Standards Association (NSF), which used to be the central body for standardisation in Norway. SN are the Norwegian member of CEN and ISO. Standards Norway adopts and publishes some 1,500 new Norsk Standard (Norwegian Standards), NS annually.

2.2.7.2. Norsk Elektrotekniske Komite (NEK)

The standardisation work for electrotechnical items is carried out in the Norwegian Electrotechnical Committee, NEK. NEK are the Norwegian member of CENELEC and IEC, and NEK adopts and publishes some 300 new standards annually. Telecommunications standards are the responsibility of the Norwegian Post and Telecommunication Authority (PT), which is the third standards writing bodies in Norway and the Norwegian national member of ETSI and ITU.

2.2.7.3. The Norwegian Water Resources and Energy Directorate (NVE)

The Norwegian Water Resources and Energy Directorate issues regulations for the shipping and offshore industries, some of which pertain to PV systems.

PV Standards

IEC 61215 is used as a quality assurance mark for the PV modules sold in the market.

Battery Standards

Most of the PV systems sold in Norway have been for the leisure market (about 70 000 PV systems for cabins exist in the mountains). These are all based on 48 V or less, and no standards are required. However, standards do exist for stationary batteries for the professional market (classified as "Standby batteries").

The standards for "Standby batteries" that are in use in Norway are: IEC 60896 Parts 1 and 2, for Vented Batteries and Valve Regulated Batteries, and IEC 60623 for NiCd-batteries. The Norwegian Coast Directorate uses exclusively NiCd-batteries in PV-systems for lanterns, and follows international recommendations. In addition the European standard EN 50272-2 for Stationary Batteries has recently been published and will be used in place of NVE / NEK regulations. These standards are listed and described in Annex 1.

The above standards form the basis of industrial (trade specific) and/or regional standards/regulations for installation and maintenance of professional stationary battery systems.

2.2.8. Portugal

There are no specific standards on PV-systems in Portugal. When standards are required IEC and CENELEC standards are applied. The main institutions in Portugal related with the standards in the area of PV systems are the IPQ and the IEP.

2.2.8.1. Instituto Português da Qualidade (IPQ)

The IPQ is the national organisation that manages and develops the Portuguese System of Quality (SPQ). In the scope of the SPQ, the IPQ is responsible in Portugal for the accreditation of entities and for national standards, as well as assuring harmonisation with European and international standards organisations. The IPQ guides the activity of numerous organisations that collaborate with it, applying the defined procedures at both European and international level.

2.2.8.2. Instituto Electrotécnico Português (IEP)

The IEP is a non-profit, private organisation, that was created to guarantee the quality of electric and electronic equipment and to promote the scientific and technological development of Portuguese industry. It represents Portugal at the international level in the IEC and CENELEC.

At present (2000) there is no specific technical committee for Portuguese PV Standards. Instead, INETI (Instituto Nacional de Engenharia e Tecnologia Industrial) is designated by IEP to provide technical comments to the draft standards developed by TC 82 of the IEC and BTTF-86-2 of CENELEC.

2.2.9. Spain

2.2.9.1. Asociación Española de Normalización y Certificatión (AENOR)

AENOR is a private organisation which develops Spanish standards in collaboration with any interested parties. It was set up by the Spanish Government in 1986 for developing standardisation and certification activities in Spain, and was officially recognised as the standardisation / certification body in 1995.

The AENOR standards and certifications are voluntary, although they are generally followed in Spanish projects. In some cases (contractual requirement, law or regulation), these standards can be obligatory.

2.2.9.2. Andalucia

In 1988 the ‘Technical PV Design and Installation Specifications’ were commissioned by the Andalucian Government. These specifications apply to all PV systems installed in Andalucia.

2.2.10.Sweden

Swedish standards for electrotechnical subjects consist mainly of European standards made available in Sweden. European standards designated as EN are published in Sweden as SS EN. European standards designated as HD, CENELEC Harmonisation Document, are published either as SS 4XX XX XX or, in accordance with the corresponding IEC-publication, as SS IEC. For example, the IEC 61277 known as EN 61277 is referred to in Sweden as SS EN 61277. Some IEC publications are also used as Swedish standards in areas where European standards are lacking. These procedures are common to most European countries.

2.2.10.1. Svenska Elektriska Kommissionen (SEK)

SEK, Svenska Elektriska Kommissionen, is the Swedish national committee in the IEC and CENELEC. It is also designated by the Swedish Institute for Standards (SIS, the central body for standardisation in Sweden), as the authorised standard body for electrotechnical issues in Sweden.

2.2.11.Switzerland

There are no specific standards for isolated PV systems in Switzerland, only simplified procedures compared to grid systems. One page (STI 232.1289) from the IFICF (see below) explains that systems below 10 kW (in three phases AC) do not need special authorisation, but that such equipment must be declared (free of charge) and the owner must prove that it is regularly checked by an electrical installer in terms of safety. The systems must follow the standard rules of the SVE / ASE. Depending on the situation (mostly on mountains), the local fire insurance company might oblige the owner to add additional lightning protection in order to cover the fire risks.

Swisssolar, which is a central organisation in Switzerland dealing with information, government programmes, etc. for the solar field, has published some technical recommendations concerning installation of low voltage PV systems, including sections on earthing and lightning protection.

The Swiss solar industry also refers to Swiss standards for lightning protection and small energy producers.

2.2.11.1. Comité Electrotechnique Suisse (CES)

The Swiss Electrotechnical Committee, CES, is responsible for electrical standards in Switzerland. CES, which is part of Electrosuisse, co-operates with other Swiss organisations and is the Swiss member of CENELEC and IEC.

2.2.11.2. Inspectorat Fédérale des Installations à Courant Fort (IFICF)

IFICF or ESTI (Eidgenössisches Starkstrominspektorat), the Federal Inspectorate For Heavy Current Installations, is responsible for inspecting low and heavy-current installations, and for promoting the electrical aspects of industrial safety. IFICF/ESTI is the highest governmental authority which establishes norms for the electrical energy producers. This also applies to SAPV systems.

2.2.12.United Kingdom

2.2.12.1. British Standards Institute (BSI)

The British Standards Institute (BSI) is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at International level. It is incorporated by Royal Charter.

Using the definition presented in BS 0, "standard" means "a document, established by consensus and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context."

The status of the British standards as noted in BS 0 is that they are voluntary. A legally binding obligation to comply with a British Standard is only created if conformity to it:

a) is claimed in the trade description of a product

b) becomes a contractual requirement

c) is made mandatory by law or regulation

Where British Standards take the form of a Code of Practice, then the standard takes the form of guidance or recommendations. In such a case the British Standard should not be quoted as if it were a specification. The legal standing of a British Standard is that compliance does not of itself confer immunity from legal obligations.

The British Photovoltaic Association (PV-UK), representing the UK PV industry, has initiated a programme of representation at the international level in PV standards. This has required the formation of a National PV Standards Committee (GEL/82) to shadow the work of IEC TC 82, under the auspices of the BSI. GEL/82 held its first meeting in October 1996. Members of BSI committees usually represent Trade Associations rather than individual companies.

Within GEL/82, no British PV standards are being developed, but a number of IEC Standards relating to PV have been published as identical British Standards (numbered BS EN 6xxxx).

2.2.13.United States of America

Although not a member of Task 3, the US is included here for completeness. US electrical installation must conform to the National Electrical Code (NEC), published by the National Fire Protection Association. PV installations are covered by section 690-*Solar Photovoltaic Systems* of the NEC.

2.2.13.1. American National Standards Institute (ANSI)

ANSI has the mandate to administer and co-ordinate the development of standards by the different organisations in the USA.

2.2.13.2. Institute of Electrical and Electronic Engineers (IEEE)

The Institute of Electrical and Electronic Engineers (IEEE), based in the US, also publishes standards on PV, which are widely accepted, and may eventually be recognised as international standards. These standards are also included in this review.

2.2.13.3. National Renewable Energy Laboratory (NREL)

NREL, the National Renewable Energy Laboratory of the US (formerly SERI), has developed a number of documents relevant to the performance and testing of stand-alone PV systems and components. These may be used as interim standards and are included in this review for completeness.

2.2.13.4. Underwriters' Laboratory (UL)

In the US, the Underwriters' Laboratory (UL) issues safety regulations. These documents are generally not concerned with performance, but with safety. In the US, electrical inspectors often refuse to accept products which have not been tested to UL specifications.

3. STATUS OF GUIDELINES & STANDARDS

3.1. Published standards

This section summarises published standards relevant to stand-alone PV systems. All standards are listed with their full title and reference number in Annex 1.

3.1.1. General and systems standards relevant to Stand-Alone PV

Most of the existing IEC standards relate to PV modules, and only a few standards cover PV terminology and aspects relating to PV systems and components. In addition there are a number of standards issued by the national standards committees. These standards are listed in Annex 1 and are described in brief here.

Two IEC standards from Working Group 1 of TC 82 give a general overview of PV systems and components, and define the terminology used in PV systems.

Working Group 3 of TC 82 deals with systems-related aspects of PV systems. Existing IEC standards relating to SAPV in general cover the following:

- Overvoltage protection, including lightning protection (of all PV systems);
- Definition of characteristic parameters for description and performance analysis of SAPV;
- PV system performance monitoring, including measurement methods, data exchange and analysis;
- Equations for deriving curves for a typical solar day.

In addition, a handbook from the Development Department of the ITU (ITU-D) details all types of power sources for remote telecommunications systems, and includes PV systems.

A Japanese standard gives quite comprehensive requirements for stand-alone PV system design. The guidelines cover system classification, selection of DC or AC system, performance, output power of PV array; output power of PV system and maximum expected consecutive days of cloudy weather; as well as operational characteristics of the PV system. They include PV system components, and the structural design of a PV system. Performance test methods are outlined, and the inspection procedure of the system installation. The labelling of a system is also described.

There are two Japanese JIS Technical Reports which give design guidelines for electrical circuit design and support structures for PV systems. A comparison of IEC and JIS standards is given in Annex 3.

Two Australian standards provide guidelines for the installation, maintenance and safety of remote power systems, and include PV systems.

An NREL document details interim test methods (in the absence of an approved standard) for measuring the performance of small PV systems, and a further NREL document provides procedures for determining the performance of stand-alone PV systems. The IEEE have published ‘recommended criteria’ for terrestrial PV power systems.

These standards are listed in Annex 1.

3.1.2. Standards for PV Modules

There are two IEC standards from Working Group (WG) 2 of TC 82 which cover the basic ‘design qualification and type approval’ of a PV module for long-term application in an open air environment. One of these pertains to crystalline silicon modules and the other to thin film modules.

A further 12 international standards from WG 2 focus on measurement devices and methods for performance testing of PV modules, for example: measurement of I-V characteristics, procedures for correction of I-V characteristic for temperature and irradiance, silicon reference cell requirements, solar simulator requirements, spectral response, and so on.

There is also an IEC standard for on-site measurement of PV array I-V characteristics. A further two IEC standards cover salt-mist corrosion and impact tests.

A European standard specifies data sheet and labelling information which should be provided by PV module manufacturers.

Several Japanese standards exist which cover subjects not yet addressed by the IEC. These give the following guidelines on PV array design and measurement: general requirements of a PV array; methods of estimating PV array performance, and on-site measurement of PV array I-V characteristics. Standards on amorphous silicon modules cover outdoor test methods of output power.

There are also Japanese standards which specifically cover the physical design , structure and performance of both amorphous and crystalline silicon PV modules.

There is a UL specification which gives construction / performance requirements and safety test procedures for PV modules in the US.

A Canadian standard dictates construction, performance and labelling requirements of PV modules in Canada. This document is currently being revised.

A DIN standard specifies data sheet and labelling information to be provided by PV module manufacturers for the German market. This is similar to the above CENELEC standard.

3.1.3. Standards for Inverters and Charge Controllers

Working Group 6 of TC 82 is dealing with work in this area. The first standard has just been published. It covers guidelines for measuring the efficiency of power conditioners for stand-alone and grid-connected PV systems.

A UL standard gives construction, performance and safety test procedures for inverters, charge controllers and AC modules.

Two Japanese standards have been published on this subject: one sets out the requirements for power conditioners and the other describes appropriate test procedures for power conditioners.

These standards are listed in Annex 1.

3.1.4. Standards for Batteries

To date there is only one published IEC standard which deals specifically with PV batteries. This was a joint project between TC 21 and TC 82. It is a general document covering basic functions, (i.e. capacity, cycle and mechanical endurance) and methods of test. It does not cover battery sizing for PV systems, or methods of charge, for example shunt / series or PWM regulation.

IEC standards for batteries generally emanate from TC 21 of the IEC. There are a number of standards from this committee which deal with batteries in general and are relevant to PV. These cover general requirements, test methods, dimensions and safety aspects for the following categories of batteries:

- Lead-acid starter batteries, i.e. lead-acid batteries used for starting, lighting and ignition of vehicles, with a nominal voltage of 12 V;

- Stationary lead-acid batteries, i.e. lead-acid cells and batteries which are designed for service in a fixed location and which are permanently connected to the load and to the d.c. power supply;

- Portable lead-acid cells and batteries, i.e. valve regulated for cyclic and standby applications, rated capacity not exceeding 25 Ah;

- Traction batteries, i.e. those normally used to power vehicles such as fork-lift trucks.

In addition, there is an IEC standard which defines the procedures for checking effectiveness of protective devices to reduce hazards of explosion, a standard for application of marking symbols for battery recycling, and a standard for monitors of traction batteries.

A Technical Report is also available which covers the opportunity charging of traction batteries, i.e. the use of free time to top up charge and extend the working day of a traction battery.

There are two relevant Japanese standards on this subject: one is for testing batteries in PV systems which have been discharged over a long period of time, and the other describes measurement procedures to determine the residual capacity of lead-acid batteries in PV systems.

There are four Recommended Practices on lead-acid batteries for PV systems available from the IEEE. These cover installation and maintenance and battery sizing for both lead-acid and nickel-cadmium batteries.

The French standard NFC 58-510 deals specifically with PV batteries. It contains:

- a glossary for the definition of the main parameters,

- functioning characteristics and accuracy of measuring instruments,

- test methods: faradic efficiency measurement, cycling and overcharge capability, mechanical endurance.

There is a number of Australian standards which cover:

- installation, maintenance and general requirements of all types of secondary batteries installed in stand-alone power systems;
- installation, maintenance, testing and replacement of vented and sealed secondary batteries (including NiCds);
- safety requirements for the installation of vented and sealed secondary batteries in or on buildings.

In addition, there is a Canadian standard giving recommendations on specifying testing and reporting battery performance, which is currently undergoing revision.

The above standards are all listed in Annex 1.

3.1.5. Standards for PV Pumping Systems

There is presently one published IEC standard which defines predicted short-term characteristics (instantaneous and for a typical daily period) of direct coupled PV water pumping systems.

This standard is listed in Annex 1.

3.1.6. Lighting standards

A comprehensive library of IEC standards has been published on fluorescent lamps and ballasts, such as are used in SAPV systems. These cover the following types of fluorescent lamps:

- Tubular fluorescent lamps
- Single-capped fluorescent lamps
- Double-capped fluorescent lamps

Each type is documented in terms of general and safety requirements as well as performance requirements.

In addition, a.c. and d.c. ballasts for fluorescent lamps are covered by the existing standards, as are starting devices.

These standards are listed in Annex 1.

3.1.7. Cabling, lightning protection and relevant electrical standards

A number of other general electrotechnical standards have been published by the IEC and CENELEC, which are applicable to SAPV systems. These embrace issues such as EMC, lightning protection, safety requirements, cabling guidelines, earthing and low voltage installations. These standards are not listed separately in this document.

3.2. Other Guidelines and Recommended Practices

This section provides a short description of several guidelines and Best Practice documents which are relevant to SAPV systems.

3.2.1. Guidelines for Stand-alone PV Systems

The CANMET Energy Diversification Research Laboratory (CEDRL) of Canada has published and maintains two documents giving technical recommendations:

- *Photovoltaic Systems Buyers Guide*

This document provides the future buyer of PV system with guidance on PV technology. The guide explains what is a PV system, what are the main components and what are the different types on the market. It provides advice on component selection although does not deal in depth with technical aspects.

- *Photovoltaic Systems Design Manual*

This document is the technical counterpart of the Buyer's guide. The document provides technical information on PV system design. It includes resource assessment worksheets, sizing techniques and advice on installing successful PV systems.

- *IEC Technical Specification*

This document is a general introduction to rural electrification using small renewable energy and hybrid systems. It is the first part of a series which intends to provide specifications for the setting up of renewable energy and hybrid systems to different players involved in rural electrification projects.

- *Specifications for Decentralised Rural Electrification*

This IEC document known as a publicly available specification (PAS) covers specifications for the use of renewable energy in rural decentralised electrification. This document is based on the French publication by EDF 'DRE Specifications' (see section 4.3.3).

- *Stand-alone Photovoltaic Systems: A Handbook of Recommended Design Practices, Sandia National Laboratories, USA, 1991*

This handbook presents recommended design practices for SAPV systems. System sizing guidelines are included and a variety of examples and exercises are shown for different applications. Widely used in the 1980s / early 1990s.

3.2.2. Guidelines for Inverters and Charge Controllers

- *Recommended Practices for Charge Controllers,* IEA PVPS Task 3, 1997

This is a document from IEA PVPS Task 3. It is intended to provide PV system users, operators and integrators with the most current information on how to choose, configure and maintain controllers in stand-alone PV systems. It applies to charge controllers of lead-acid batteries only, not nickel cadmium or other battery technologies.

3.2.3. Guidelines for Batteries

- *Guidelines for the use of batteries in photovoltaic systems,* Natural Resources Canada / Neste Oy, 1998

A book written in a collaborative project between Natural Resources Canada and Neste (Finland). The book is aimed at providing quality procedures to buy and use batteries in PV systems. Intended for designers and users of SAPV systems, providing detailed information on battery selection, and how and when they should be used.

- *Lead-Acid Battery Guide for Stand-Alone Photovoltaic Systems,* IEA PVPS Task 3, 1999

This is a document from IEA PVPS Task 3. It is a compilation of general information on lead acid batteries for professional users. This information is seldom available for the user/installer of stand alone PV systems. By using the information given in the guide, the battery lifetime can be extended and the PV system lifecycle cost can be reduced substantially.

The more specific advice in this guide is written *for open (also called vented) lead acid batteries* as these are still the most common type selected in SAPV systems due to significantly lower initial investment costs. The safety advice is also an important part of the guide.

3.2.4. Guidelines for PV Pumping Systems

- *Le pompage photovoltaïque – Manuel de cours à l'intention des ingénieurs et des techniciens*

This book is a joint publication by Institut de l'énergie des pays francophones, University of Ottawa, EIER (Burkina Faso) and CREPA (Burkina Faso). It is aimed at teaching how to install quality PV water pumping systems.

3.3. Draft Standards

This section summarises all the standards currently in draft format, which are relevant to stand-alone PV systems. All draft standards are listed with their full title and reference number in Annex 2.

3.3.1. Draft PV Standards Relevant to Stand-Alone PV

The IEC Technical Report covering terms and symbols is currently being revised.

An IEC standard for the design verification of SAPV systems is being drawn up. This is also a new work item for CENELEC.

An IEC Technical Specification with recommendations for small renewable energy and hybrid systems is being developed. The document consists of several parts covering different aspects.

An IEC standard on PV electricity storage systems is also being considered as a potential new work item of Working Group 4, but progress has been slow with this document.

There are three Japanese standards under development which are relevant to this subject, one is concerned with the electrical safety of PV systems on houses and the other deals with the structural design and installation of rooftop PV arrays.

These standards are listed in Annex 2.

3.3.2. Draft Standards for PV Modules

Several existing standards on PV modules are currently being revised and updated. These are listed in Annex 2.

IEC safety testing requirements are being drafted for PV modules. These are due to be published in 2004.

Work on an IEC standard recommending performance testing and energy rating methods for PV modules has started, but no Committee Draft has been circulated yet.

Work on new standards setting out the blank detail specification for a PV module and on PV concentrators is being considered.

In CENELEC, work has started on safety class definition and on norm sizes for PV modules.

These draft standards are listed in Annex 2.

3.3.3. Draft standards for Inverters and Charge Controllers

Two IEC standards are currently being worked on by Working Group 6. The first of these will cover environmental reliability of BOS components and is now a Draft International Standard. The second standard, which consists of three parts, focuses on electrical safety of inverters and charge controllers. The three parts currently have the status of Committee Draft / Approved New Work.

CENELEC is working on a draft standard for stand-alone and grid-connected inverters.

These standards are listed in Annex 2.

3.3.4. Draft standards for Batteries

There is currently no ongoing standards work on batteries for use PV systems.

3.3.5. Draft standards for PV Pumping Systems

The IEC recently proposed a new work item which covers the design qualification and type approval of direct-coupled PV pumping systems. Unfortunately this standard was not approved by TC82 for further development.

4. QA ORGANISATIONS AND PROCEDURES

4.1. Overview of International QA Organisations

4.1.1. Conformity Assessment within the IEC

Within the IEC, there are three bodies with responsibilities for conformity assessment. They all report to the Conformity Assessment Board and cover the following areas:

- IECQ Quality assessment system for electronic components
- IECEE System for conformity testing and certification of electrotechnical equipment and components
- IECEx Scheme for explosive environments

The **IECQ** is a third-party certification system for the conformity of electronic components to specified quality requirements. Since its inception, IECQ has offered a comprehensive world-wide programme that provides relevant, ongoing quality assessment for customers and suppliers in the electronics industry. Assessment of supplier quality management is an integral part of IECQ.

An approval under the IECQ system entitles its recipient to dual certification to defined IECQ requirements and an ISO 9000 standard. Similarly, approval of test laboratories includes dual certification to the requirements of IECQ and ISO / IEC Guide 25.

The **IECEE** or 'system for conformity testing and certification of electrotechnical equipment and components' operates the **CB Scheme** ("Scheme of the IECEE for Mutual Recognition of Test Certificates for Electrical Equipment"), which is an international system for acceptance of test reports dealing with the safety of electrical and electronic products. It is a multilateral agreement among participating countries and certification organisations. A manufacturer using a CB test report issued by one of these organisations can obtain national product certification in all other member countries of the CB Scheme.

The Scheme is based on the use of IEC Standards. The CB Scheme uses CB Test Certificates to attest that product samples have successfully passed the appropriate tests and are in compliance with the requirements of the relevant IEC Standard and with any declared national differences of various member countries.

The main objective of the Scheme is to facilitate trade by promoting harmonisation of the national standards with international standards and co-operation among product certifiers worldwide in order to bring product manufacturers a step closer to the ideal concept of “one product, one test, one mark”.

All countries which have membership in IEC may join the IECEE. The National Committee of each member country must then designate its National Certification Body or Bodies (NCB) which will be responsible for recognising and issuing CB Test Reports and Certificates.

The **Full Certification Scheme (CB-FCS)** is an extension of the CB Scheme and is an option which may be exercised by any of the participating NCBs. It is based on the concept of acceptance of Conformity Assessment Reports (CAR) and Conformity Assessment Certificates (CAC) attesting conformity with the requirements of a “benchmark” certification system and any declared differences from the benchmark system.

A participating NCB carries out and documents in the “CAR” all conformity assessment activities on a manufacturing facility and its product as required by NCBs in the product’s destination countries. This in turn should provide a streamlined one-stop conformity assessment process for manufacturer’s product certification needs.

The benchmark system requires an assessment of manufacturer’s quality assurance program, type testing, and follow-up surveillance consisting of periodic quality system audits and testing of samples from factory or the open market. The scheme intends that NCBs carry out initial factory assessments as well as post-certification surveillance activities on each other’s behalf. It is recognised that this may require agreements between participating NCBs.

Manufacturers who wish to use this scheme will be required to use a documented quality system. The manufacturer’s in-plant conformity assessment procedures must include applicable production line inspections and routine tests as well as selected type tests that are specified for some product categories. If a manufacturer’s quality system is already registered to the ISO 9001 or ISO 9002 standards by an accredited registrar, this will be taken into account in determining compliance with QA system requirements of the CB-FCS Scheme.

Initially, PV-GAP was working through the IECQ on QA for PV systems. From 2004, IECEE took over conformity assessment for PV from IECQ. Conformity assessment for PV will be under the Full Certification Scheme (CB-FCS).

4.1.2. Global Approval Program for Photovoltaics (PV GAP)

The Global Approval Program for PV (PV GAP) was established to promote high standards for the production, installation and servicing of PV systems. The need for PV GAP was identified at an industry meeting on system reliability at the European PV Conference in Nice in October 1995. Participants were concerned about PV developing a poor reputation due to the sale and installation of unreliable systems and components. The founders met at the IEEE PV Specialists Conference in Washington DC in April 1996, when the World Bank, UNDP and the Rockefeller Brothers Fund participated and endorsed the initiative. PV GAP was formally launched at the European PV conference in Barcelona in July 1997.

PV GAP is a Swiss-registered non-profit organisation that focuses on certifying the quality of PV systems. PV GAP also concentrates on the enforcement of international standards that promote the integration of quality. The organisation will work to get testing standards into the financing stream, such that finance for a project is conditional on PV GAP approval. It will also establish international reciprocity of recognition of standards and testing laboratories.

PV GAP intends to complement the work of IEC and will use standards published by IEC, but will also prepare its own interim standards until IEC standards become available. Manufacturers, distributors and installers that are approved under PV GAP will be licensed to utilise and display a distinctive 'PV Quality Mark' for components and a 'PV Quality Seal' for PV systems. PV GAP differs significantly from the IEC in that it is market and industry driven.

The first draft version of the PV GAP Reference Manual was published in February 1998. It comprises the following parts: General; Approval Process; Standards; Statutes and Bylaws; and Glossary of Terms. Interim standards have been developed by PV GAP and are included in the PV GAP handbook. These will be withdrawn once suitable IEC standards have been developed.

4.1.3. Institute for Sustainable Power (ISP) Training Accreditation and Certification

The Institute for Sustainable Power, Inc. (ISP) is a non-national, non-profit organisation created in 1996 with the goals of improving the quality of renewable and sustainable energy projects, and improving the quality of workforce development for sustainable, local jobs. ISP provides a quality infrastructure framework for the accreditation of renewable energy, energy efficiency, and distributed generation training programmes; the certification of renewable energy, energy efficiency, and distributed generation trainers; and the registration of programme evaluators and auditors. The intention is that ISP will work in close collaboration with PV GAP. The accreditation will give funding organisations a third party assurance of the professional skills and capabilities of any training centre or course active in the PV industry.

4.2. International QA Procedures and Best Practices

4.2.1. ISO 9000

The ISO 9000 series of documents was created by the International Organization for Standardization (ISO) to set international requirements for quality management systems. Now adopted by over 80 countries, use of the series of standards has become commonplace in the business world. The series itself is generic, and is designed to be applicable to any manufacturing or service process. The series is modified periodically. The original standards were published in 1987, first revised in 1994 and the current versions were issued in 2000.

The previous ISO 9000 family of standards contained some 20 standards and documents. The year 2000 ISO 9000 family of standards consists of four primary standards supported by a number of technical reports. The four primary standards are:

- ISO 9000: Quality Management Systems - Concepts and Vocabulary
- ISO 9001: Quality Management Systems - Requirements
- ISO 9004: Quality Management Systems - Guidelines
- ISO 19011: Guidelines for quality and/or environmental management systems auditing

The last of these documents is a joint auditing standard for both quality and environmental management systems. It was published by ISO in 2002 and replaces six older standards in the ISO 9000 (quality) and ISO 14000 (environment) families. Its use will give organisations a more integrated and balanced view of their operations, making it an outstanding tool for continuous improvement towards business excellence. It is also aimed to help user organisations optimise their management systems and facilitate the integration of quality and environmental management.

A certified Quality Management System demonstrates an organisation's commitment to quality and customer satisfaction. Implementing a Quality Management System will help to enhance customer satisfaction, achieve consistency, and improve internal processes, and can minimise the risk that customer expectations are not met.

4.2.2. PV GAP

Part III of the PV GAP Reference Manual is a collection of PV GAP ‘Recommended Standards’. These standards were developed by experts from the PV industry and other organisations, and are recommended for use as interim standards until the corresponding IEC standards are completed and published. It is stressed in the PV GAP reference manual, however, that acceptance of these standards is voluntary, and that PV GAP cannot be held liable for them.

<u>PV GAP Recommended Standards</u>

- *PVRS 1 First Edition 1997-10 Photovoltaic Stand-Alone Systems - Design Qualification and Type Approval.*

This is an interim ‘recommended standard’ which is to be used until IEC standards on SAPV systems are completed. It covers components and indoor testing, and is based on testing experience at the European Commission's Joint Research Centre in Ispra.

Part A of the document gives indoor test specifications for PV modules, charge controllers, and batteries. There are no test specifications for appliances at this stage.

Part B gives test procedures for:

- assembly / installation of a system;
- performance rating (sizing check) of SAPV with array of less than 1000 W (indoor tests);
- performance tests under operating conditions (PTOC), i.e. determines operating parameters;
- verification of sizing of Solar Home Systems (one household with lighting, radio and optional TV), includes systems with inverters, and recommended cabling sizing.

- *PVRS 2 Second Edition 2003-08 Crystalline silicon terrestrial photovoltaic (PV) modules. Blank detail specification.*

This is an interim 'recommended standard' which is essentially a pro-forma enabling a manufacturer to provide written certification that a crystalline silicon module performs according to IEC 61215. It also states the additional testing requirements for any modifications to an approved module design.

- *PVRS 3 First Edition 1999-05 Thin film terrestrial photovoltaic (PV) modules. Blank detail specification.*

This is an interim 'recommended standard' which is essentially a pro-forma enabling a manufacturer to provide written certification that a thin film module performs according to IEC 61646. It also states the additional testing requirements for any modifications to an approved module design.

- *PVRS 4 Third Draft 2002-12 Stand-alone photovoltaic (PV) systems, with a system voltage below 50 V.*

This is a draft interim 'recommended standard' which is a pro-forma enabling written certification that an SAPV system conforms to the outdoor testing requirements of a previous draft IEC standard based on an NREL document (IEC 82/218/NP).

- *PVRS 5 Lead-acid batteries for solar photovoltaic energy systems (modified automotive batteries). Blank detail specification.*

Based on a CENELEC draft (now withdrawn) which will make batteries certifiable.

- *PVRS 5A Lead-acid batteries for solar photovoltaic energy systems - General requirements and methods of test for modified automotive batteries.*

Describes general requirements and methods of test for modified automotive lead-acid batteries used in PV systems.

- *PVRS 6 First Edition 2000-06 Charge controllers for SAPV systems with a nominal system voltage below 50 V. Blank detail specification.*

Based on GEF WB-China Renewable Energy Development Project specifications. Will enable certification of SAPV systems to aforesaid specifications.

- *PVRS 6A First Edition 2000-06 Annex to PVRS 6: Specification and Testing Procedure.*

Reproduced by permission of the PMO, GEF WB-China REDP specifications, May 1999, Beijing.

- *PVRS 7 First Edition 2003-07 Lighting systems with fluorescent lamps for photovoltaic (PV) stand-alone systems with a nominal system voltage below 24 V. Blank detail specification.*

Based on GEF WB-China RED specifications and on CENELEC BTTF 86-2 work.

- *PVRS 7A First Edition 2003-07 Specification and testing procedure, to PVRS 7.*

Based on GEF WB-China RED specifications and on CENELEC BTTF 86-2 work.

- *PVRS 8 First Edition 2000-06 Inverters for photovoltaic (PV) stand-alone systems. Blank detail specification.*

Based on GEF WB-China RED specifications. Makes GEF WB-China RED specifications certifiable.

- *PVRS 8A First Edition 2000-06 Annex to PVRS 8: Specification and Testing Procedure.*

Reproduced by permission of the PMO, GEF WB-China REDP specifications, May 1999, Beijing.

- *PVRS 9 First Edition 2000-01 Procedures for determining the performance of stand-alone photovoltaic systems.*

This is document NREL/TP-520-27031, which was prepared by authors from NREL, Sandia National Laboratories, Florida Solar Energy Center, Southwest Technology Development Institute, and Photovoltaics for Utility Scale Applications.

The procedures cover complete outdoor system testing and provide a common approach for evaluating whether a given PV system is suitable to perform the function for which it was designed and manufactured to accomplish, and whether it will provide adequate power to run the load.

- *PVRS 10 Code of Practice for Installation of Photovoltaic Systems.*

Code of practice for the installation of PV systems.

4.2.3. World Bank ASTAE Quality Management in Photovoltaics (QuaP-PV)

The ASTAE Unit of the World Bank has recently financed the development of four QA manuals and associated training programmes, with funding provided by the Dutch Government:

- Quality Management in Photovoltaics: Manufacturers Quality Control Training Manual;
- Manual for design and modification of solar home system components;
- Training Manual for Quality Improvement of Photovoltaic Testing Laboratories in Developing Countries;
- PV Installation and Maintenance Practitioner Certification Infrastructure: Development Procedures.

These documents are basically training manuals to enable manufacturers of PV components, testing laboratories and organisations responsible for the training of installation personnel to gain an understanding of quality issues and to initiate quality schemes based on the ISO 9000 series.

4.2.4. World Bank ASTAE Best Practices for Photovoltaic Household Electrification Programmes

This document, published by the World Bank ASTAE Unit in 1996, collates best practices for PV electrification programmes based on experiences in Indonesia, Sri Lanka, the Dominican Republic and the Philippines. It presents ‘key ingredients’ for successful residential PV programmes, and ways to overcome financial and institutional barriers to programme implementation.

The executive summary lists a number of factors responsible for early PV programme failure. These include unreliable technical performance, poor system design, lack of ongoing, qualified technical support, shortcomings of the implementing agency, poor attention to cost recovery, and unrealised user expectations with consequent dissatisfaction. It then identifies four main areas, including quality, where attention should be focused to ensure successful programmes:

- overcoming the first cost barrier;
- establishing responsive and sustainable infrastructure;
- providing quality products and services;
- identifying the role of governments and donors.

The chapter on Technical Requirements includes sections on standards and specifications, warranties, and Quality Control / Assurance. On standards, it recommends that governments or technical agencies set standards and specifications for Solar Home Systems, and ensure that these are enforced by the appropriate body. It defines *prescriptive* and *performance* specifications, where the former outlines the requirements for each component in terms of size and rating, whilst the latter details the output or service that must be provided by the system. The report comments that performance specifications allow designers greater freedom to optimise the design configuration, but can make verification of system performance difficult.

With respect to warranties, the study comments that various lengths of warranty are available depending on the manufacturer. The important point is to make realistic provisions for enforcing warranties in order to protect the consumers.

Lastly the report notes that quality assurance procedures should address all links in the chain of designing, specifying and supplying a PV system to the end-user. This includes quality in manufacturing, component purchase, system assembly, testing and installation. The training of technicians in system installation is also important. The study reports on experience in China and Sri Lanka which showed that good quality procedures improved profitability of projects.

4.2.5. Universal Technical Standard (UTS) for Solar Home Systems (SHS)

The Instituto de Energia Solar (Spain) has drawn up a proposed standard for SHS, in conjunction with JRC Ispra (EC), GENEC (France) and WIP (Germany) within the framework of the European THERMIE B programme (SUP-995-96).

This document, the Universal Technical Standard for Solar Home Systems (UTS), intends to provide the basis for a global standard for SHS and makes use of standards and guidelines from around 20 countries, many of which are developing countries.

The authors undertook a world-wide review of existing technical standards, from countries including Bolivia, Brazil, India, Indonesia, Kenya, Mexico, Sri Lanka, Sahel, Tunisia, Zaire and South Africa, as well as OECD countries such as France, Germany, Spain and the USA. It is noted that there were a large number of inconsistencies between these standards, for example, in system sizing methods, charge regulation set points, user operational information and so on. In order to reach a conclusion, each of the different approaches were evaluated using the scientific reasoning, empirical evidence and experience of the authors.

The authors also consulted key people in rural electrification programmes, to include advice from those with experience in the field. The most frequent request was for flexibility. For this reason, the UTS classifies requirements into three categories: Compulsory, Recommended and Suggested.

The UTS is intended to provide a basis for technical QA procedures, to the extent that meeting the specified requirements will ensure that a SHS will perform properly. It has been written to provide a quality reference for national governments, donors and investors.

The UTS introduction acknowledges that the standard is limited to the specifications of SHS. It does not include the definition of test procedures, although the standard is written such that these can be easily added.

The UTS is also limited to the technical aspects. It is stated in the introduction that items such as guarantees, documentation, spares, labels etc, are also necessary to the quality and success of PV rural electrification by SHS. However, it is also pointed out that such items are heavily influenced by local conditions, so that they do not readily lend themselves to universal standardisation.

Another interesting experience of the authors was that technical solutions to the same problem vary from country to country. For reasons of flexibility, a conscious decision was taken to use some general terminology, so as to encompass the solutions of each region. For example, the terms ‘adequate fixing’ and ‘widely acceptable’ are used, and it is up to the local technical experts (the respective accredited test centre) to use their judgement as to whether these requirements have been fulfilled.

4.2.6. PV Market Transformation Initiative (PVMTI) Guidelines

PVMTI is a major PV implementation programme with 25 MUSD of Global Environment Facility (GEF) funds to support private sector, competitively solicited solar PV market development projects. It is intended to catalyse the PV market in three key developing countries: India, Kenya and Morocco. It is anticipated that with leverage, around 100 MUSD will be invested. As such, the standards and specifications recommended for selection of projects by the management team is worth noting. The management team is led by IT Power and Impax Capital (UK).

The PVMTI Country Managers for India produced a report entitled ‘Accreditation of PV systems, Modules and BOS Testing and Certification Organisations in India for PVMTI investments’. This document surveys the capabilities of Indian laboratories for testing of PV systems and components, and presents those that have been selected for testing products and systems invested in by PVMTI. In addition, it reviews national and international standards related to PV systems, including IEC standards, PVGAP and the UTS. The report recommends the procedure to be followed for certification of products from companies invested in by PVMTI, and for accreditation of those companies.

The situation in Morocco and Kenya is similar to that in India, where the UTS is the recommended protocol for Solar Home Systems, and all other SAPV products and systems are to be evaluated under the PV GAP recommended standards.

4.3. National QA Procedures and Best Practices

4.3.1. Quality Standards of Solar Home Systems in South Africa (Spain)

This final report of an EC APAS project, written by PV LabIER – CIEMAT (Spain) and EDRC (South Africa) in June 1996. The work reported was conducted for the project ‘scheme for large-scale implementation of SHS in South Africa’ (CEC contract RENA-CT94-0048).

The report documents existing international standards at that time and identifies an absence of standards for charge controllers, batteries and luminaires, and stand-alone systems in general. New testing procedures and acceptance criteria were then developed to aid the quality selection of components in South African PV programmes. These criteria also cover system design, operation and maintenance. These documents are included as Annexes to the report.

The EDRC in South Africa has also been working with the South African Bureau of Standards on specifications for SHS. A *Code of Practice for the Installation of Low* *voltage PV Systems*, as well as technical schedules and installation acceptance tests have also been drafted for discussion with the relevant South African institutions. Much of this is extremely relevant to the QA of SHS. These documents are also included in the report Annexes.

4.3.2. Basic Electrification for Rural Households: Experience with the Dissemination of Small-scale Photovoltaic Systems (Germany)

This guidebook was published by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in 1995. It is described as 'A Guidebook for Decision-makers, Planners and Suppliers', and provides a thorough examination of technical and institutional issues surrounding the implementation of PV programmes in developing countries, based upon GTZ programme experience.

The study intends to provide both an overview and a critical assessment of the PV projects that were implemented by GTZ prior to 1992 and to develop analytical tools which make it possible to identify sound approaches to the design of PV programmes.

In addition to illustrative examples from various GTZ PV programmes across the world, including Peru, Colombia, Senegal, Rwanda, Tunisia and the Philippines, the book includes a review of alternative SAPV system layouts, for example central station village power supply systems, solar battery charging stations, solar lanterns, and Solar Home Systems. The comparative economics of these systems are presented, and appropriate users of each system type are identified according to income.

Technical chapters, suitable for the non-technical reader, are included on the basic functions of SAPV system components, and the results of testing by the Fraunhofer Institute for Solar Energy on BOS components, including some appliances, from the programmes are also presented. Components from both local and international companies were tested and compared for performance and price. The minimum requirements for each of the SHS components are defined in the book. Lastly, the book presents alternative implementation and financing strategies, and comments on their merits

The study also includes a chapter which discusses the use of locally produced components, as opposed to those imported from, for example, Germany. The quality implications of this are analysed, and the chapter concludes that the introduction of quality standards are imperative to the success of future PV programmes, particularly for electronic components of SHS. For this reason, GTZ had formulated a set of minimum technical requirements for SHS, and commissioned the Fraunhofer Institute for Solar Energy to test electronic products from various sources against these requirements. Each component was then assigned a quality rating. The data from these tests serve as a basis for the procurement policy of GTZ, and also for any advice given by GTZ to SHS distributors in developing countries. The report comments that the World Bank had also expressed an interest in using the results of the independent evaluation of SHS components.

4.3.3. DRE Specifications for the use of renewable energies in rural decentralised electrification (France)

The French *General Directives for the use of REN in Decentralised Rural Electrification* (1998) also known as the 'DRE specifications' comprises three parts which deal methodically with all standards and regulations pertaining to the selection, design, installation and operation of a rural electrification system based on PV or wind. IEC, European and French standards are referenced as appropriate and system characteristics, design and installation procedures are defined. The following topics are included:

Part A : From Energy Requirements to Electrification System

This part covers energy needs identification; methods for characterising needs; guidelines on selecting a system; expected outputs of the system design; contractual framework; and Quality Assurance for project design and implementation.

Part B : Rules on the Design and Operation of Systems

This covers electrification system architecture; guidelines for design of the sub-systems for generation and distribution; the functional description of private electrification systems, micro grids and micro power stations; guidelines on energy management and Data Acquisition Systems. It also includes sections on operation and maintenance of the system; climatic and environmental testing; recycling and protection of the environment, and protection of persons and property from electrical hazards.

Part C: Technical specification of components

This part covers the PV array, building integration of PV arrays, wind generators, generator sets (fossil fuelled), batteries, inverters, charge controllers, energy management systems and the customer interface. It also includes sections on micropower stations, microgrids, domestic installations, lighting loads and hydraulic micropower stations.

4.3.4. SEBA Draft procedure for assessing the performance of quality of service provided by stand-alone PV hybrid system installations (Spain)

The Spanish energy operator for stand-alone PV hybrid systems, SEBA, has a draft procedure for assessing the performance of the quality of service provided by stand-alone PV hybrid installations. SEBA has written these guidelines specifically because there were no such standards previously available, and SEBA required such a document for its own installations.

4.3.5. Quality Standards for Solar Home Systems and Rural Health Power Supply (Germany)

This report was published by GTZ in February 2001. It provides an overview of standards that are relevant for Solar Home System (SHS) and Rural Health Power

Systems (RHS). It is intended to facilitate selection of components and systems, particularly in tenders, and to provide impetus for standardisation. Moreover, it identifies components for which there is a need for technical specification.

Eleven different documents which provide specifications for PV systems and components were evaluated for the study and summarised in a table. Based on these documents, standard specifications have been prepared which may be used directly as text modules in international tenders. The report draws up minimum requirements which should enable the procurement and installation of a reliably functioning Solar Home System, according to the current state-of-the-art.

The report observes that components and systems for RHS should meet higher standards than SHS, and these have also been evaluated and compiled accordingly. A separate set of standard texts for tenders for PV pumping systems has also been produced, ref. ‘Proposal for Tender Documents for the Procurement of PV Pumping Systems (PVP)’, GTZ, Div. 44, Sustainable Energy Systems.

4.3.6. Indonesia Solar Home Systems Project: ‘Specifications for Solar Home Systems’ (rev. 1998) and ‘Test Procedures for Battery Charge Regulator and Lighting Fixture’ (1999)

These specifications were written for the Indonesian Solar Home Systems project, which was approved by the World Bank in 1997. The project consists of two major components: (1) a credit component comprising a World Bank IBRD loan and a GEF grant, to enable purchase of solar home systems by rural households and commercial establishments on an instalment plan basis; and (2) technical assistance, including support of detailed monitoring and evaluation activities during project implementation. The principal objectives of the Project were to provide PV electricity to rural customers whilst facilitating private sector participation in the commercialisation of renewable energy in Indonesia. The economic situation in Indonesia greatly limited the success of the project and has resulted in the subsequent closure of the IBRD loan. The project is being continued on a much smaller scale with the GEF grant only.

The specifications themselves were intended to provide suppliers of hardware with the minimum requirements for tender. The documents are reasonably brief – around 15 pages each, and they include the following:

- *SHS Component Specifications* - All products to be financed under the IBRD loan must have a type-test certificate from an ISO 25 accredited testing laboratory, which ensures compliance with these specifications. The specifications cover the items listed in the table below.

Table 1: Indonesia SHS system specification contents

General: warranties on components (for example PV modules warranted against reduction of output of no more than 10% rated capacity over ten year minimum period) maintenance, etc; *Operating environment*: describes conditions and factors which equipment must withstand; *PV array:* minimum requirements of array, e.g. minimum power, certification required to IEC standards, labelling etc.; *Battery:* self-discharge rate, cycle life, certification according to Indonesian battery standards;	*Charge controller:* set points, current and voltage rating, power consumption, labelling; *Protective devices:* blocking diodes, reverse polarity and short circuit protection, means of safe disconnection; *Load control:* low voltage disconnect specifications suitable to protect automotive lead-acid batteries; *Fluorescent luminaires:* covers ballasts, efficiency, minimum frequency and maximum voltage etc. *Socket outlet:* current rating, polarity protection.

- *SHS Specification Sheet* - a proforma to be completed with information describing the system;
- *Recommended Best Practices* - covers PV modules installation, circuit protection and charge controls, monitoring, batteries, enclosures, and wiring;
- *Recommended documentation* – suggests contents of users manual and technicians manual. The latter includes post-installation acceptance test procedures and recommends an annual maintenance schedule and trouble shooting guide;
- *Recommended packaging and delivery* – states that supplier should pre-assemble system and take responsibility for damage to shipped goods;
- *Test Procedures for Battery Charge Regulator and Lighting Fixture* - these Test Procedures have been devised in order to test charge controllers and fluorescent lights for compliance with the component specifications listed above.

4.3.7. Sri Lanka: Energy Services Delivery Project 'Specifications for Solar Home Systems' (rev. 1999)

This document provides specifications for the Solar Homes System component of the World Bank - International Development Agency / GEF funded Energy Services Delivery Project, which was approved by the board in 1997.

The specifications are essentially the same as those provided for the Indonesia project described in Section 4.3.6 above, although the 'Best Practice' description has largely been incorporated into the specifications themselves. They do not include the Test Procedures document.

4.3.8. South Africa: Solar Home System Specification NRS-052

These recent specifications draw on material from Eskom (the South African state utility), from the EDRC (Energy for Development Research Centre), and from commerce and industry. They were devised to standardise requirements for four types of Solar Home Systems, under 150 Wp, to be installed under a national programme. The document is very comprehensive, and is divided into two sections:

- Part 1: *Standardised requirements for application in a national programme to provide solar power to individual homes remote from the electricity grid.*

This section comprises the technical specifications and is around 40 pages long, excluding annexes. It includes references to all relevant international and South African standards. It then outlines the technical requirements for the solar home system types defined by the programme, including sections on each SHS system component, which extends to cover inverters, DC lights, switches, and cabling.

The O&M manual to be provided to the purchaser is also described, and is to include operating instructions and troubleshooting advice in order to enable adequate on-site maintenance. It is stipulated that this manual also contains advice about load management, safety, and an installation guide, as well as specifying the guarantee periods and expected lifetime of components.

The guidelines then provide installation specifications, which include PV array mounting recommendations, site selection, cabling and conduit sizing, rating and installation, earthing / bonding of the system, battery and lighting installation, and component enclosures.

A further section deals with testing of the components and system. Part 2 is referred to for test procedures of components. In addition, a basic test procedure for the whole system, which includes tests on the PV array, the regulator and the inverter as well as checking for earth faults, is described in Part 1.

Lastly the requirements for labelling and packaging for delivery are described. The annexes to the specifications contain relevant technical information (e.g. a battery trouble shooting guide and cable cross section selection) as well as documents related to the programme (e.g. model notes to tenderers, warranty conditions etc).

- Part 2: *Test Procedures for main components*.

This section comprises test procedures for PV modules, batteries, regulators, inverters and DC lighting.

4.3.9. PV Solar Home Systems Specifications and Component Testing Procedures (China)

The Project Management Office (PMO) of the World Bank / GEF Assisted Renewable Energy Development Project has published an Information Package for PV Solar Home Systems Specifications and Component Testing Procedures (May 1999). This package is designed to be used by prospective suppliers to the programme and can be downloaded from the project web-site.

These documents are the first comprehensive package of specifications for such a programme. They include specifications and qualifying requirements for both PV and PV/wind hybrid systems (without auxiliary back-up). Requirements for overall system design as well as certification of components for reliability, environmental robustness and warranties are covered.

The documents list technical requirements for PV modules, wind turbines, stand-alone inverters, charge controllers, d.c. fluorescent lights, wiring and power outlets. Installation documentation, acceptance tests and system delivery constraints are also specified.

Test procedures for all major system components are defined. Instructions for testing of components are also included, and organisations are encouraged to apply for accreditation as a test centre. Design assistance is available on request from the PMO.

5. REVIEW OF WORK NEEDED

5.1. Standards for stand-alone PV systems

At present, several international bodies (CENELEC, PV GAP, IEC) are involved with the development of standards covering the system aspects as well as typical components of small stand-alone PV systems.

Experience shows that the quality of systems installed is variable, especially in developing countries. There is also often a lack of confidence in the ability of PV to give a reliable supply of power in remote locations. This underlines the urgent need for standards in this area. PV GAP was initiated by industry to address this problem.

The technical committees in both IEC and CENELEC have realised the importance of this area and have started to work on draft documents.

The following issues are currently being discussed by the PV community, and standards are being drafted:

- System aspects – SAPV, PV pumping
- Certification and accreditation of PV systems
- Batteries for application in PV systems

- Charge controllers and inverters
- Lighting components

The following issues would also benefit from new standards and guidelines:

- System aspects – PV hybrids
- Acceptance tests for SAPV systems
- Recommendations for the proper management of load appliances used in SAPV systems

International standards for SAPV systems are limited in their coverage. The French, Japanese and US PV industries have published their own guidelines which cover various aspects of SAPV system design and performance characteristics. PV GAP Recommended Standard PVRS1 details basic characteristics and indoor test methods for SAPV systems. Draft standards on system aspects need to be reviewed by system designers, suppliers and test institutes. The standards should also be critically assessed with respect to their application to small professional systems.

Standards for PV pumping systems and hybrids are also required for the supply and installation of quality systems, but these are not yet being drafted. A PV pumping standard is included in TC82's Work Programme as a new work item, but so far the progress of this document has been slow. The GEF / World Bank China Renewable Energy Development Project specification includes qualifying requirements for PV-wind hybrid systems (without auxiliary back-up).

Batteries are an essential part of most stand-alone PV systems, and system failure can often be attributed to battery failure. At present, there is only one ‘PV-specific’ IEC battery standard. The PV community should take a lead in the development of standards on batteries for PV systems, as they are an important system component. As the PV market is much smaller than, for instance, the traction or automotive market, the battery industry is unlikely to lead the way in the development of PV-specific battery standards.

Charge controllers are also an important component of most stand-alone PV systems. A properly designed charge controller is essential in order to obtain an acceptable battery life. At present, there is only one published international standard on this subject, although further documents have been drafted by the IEC and CENELEC, and the US and Japan have published their own standards. In the interim, a PV GAP Recommended Standard has been published, which is based on the GEF / World Bank China Renewable Energy Development Project specification.

Many stand-alone PV systems use inverters to enable AC loads to be powered. There is one published international standard on this subject, which deals with efficiency testing. Working Group 6 of IEC TC82 is working on further draft documents. CENELEC is also working on a pre-standard which governs performance requirements for grid-connected and stand-alone inverters. The development of this draft document should be followed.

Most small stand-alone PV systems power lights, so there is a requirement for standards for lighting components for use in PV systems. These standards should tie in with standards on lighting components used in other areas.

The loads used in SAPV systems have a great impact on the operation and efficiency of the system. Recommendations on the selection and application of these loads would be a step towards better load management.

5.2. QA procedures for stand-alone PV Systems

Quality issues have recently been introduced to the TC 82 work programme. The certification and accreditation for PV components and systems has been the starting point and further standards in this area are expected. A Spanish organisation, SEBA, has drafted its own standard for assessing the performance of the quality of service provided by stand-alone PV hybrid installations, to be applied to systems operated by SEBA.

5.2.1. Accreditation of testing laboratories

The PVGAP adopted the internationally accepted approval system of ISO / IEC Guide 25 to qualify testing laboratories world-wide. Under the IECQ approval system, both independent testing laboratories and PV company testing laboratories could be certified. The certification was administered by the National Supervising Inspectorates (NSIs) of IECQ, such as VDE in Germany and UL in the USA.

When IECEE took over the role of conformity assessment for PV from IECQ (in 2004), the Testing Laboratories that were operating within the IECQ PV Programme were granted acceptance by the IECEE for three years. From January 2007, these Testing Laboratories will be subjected to the current IECEE Peer Assessment Programme to show compliance with ISO/IEC 17025, and with the applicable IECEE Rules and Procedure. Manufacturer Testing Laboratories (MTLs) that were operating within the IECQ PV Programme were also granted acceptance by the IECEE. MTLs will be subjected to the current Assessment Programme, by the responsible Certification Body to show compliance with the relevant part of ISO/IEC 17025, applicable IECEE Rules and Procedure.

Adopting the IECEE system ensures reciprocity of the testing laboratories. This means that re-testing of components in different countries will no longer be required. In addition, the development of a larger number of qualified testing laboratories will reduce the cost of sending components to other countries for testing and accelerate the approval of system components.

5.2.2. Training and certification

In order to ensure that quality systems are provided, it is essential that the technicians who design and install the system receive the necessary training. At present, there is no globally accepted programme for training PV engineers and technicians. As a result, different countries and organisations have devised a small number of independent training programmes, which are not generally recognised by other organisations and countries. Many technicians, and their respective trade associations, assume that a general training as an electrician is sufficient to enable them to install PV systems correctly, but experience shows that this is frequently not the case.

To date, most training efforts in PV system design, installation and maintenance have been implemented without clear competence targets, so the effectiveness of the training cannot be properly judged. In addition, the various training programmes rarely build upon one another, and isolated training programmes are instead devised and undertaken around the world.

The Institute for Sustainable Power in the USA has recognised this problem and is driving a programme to develop a globally recognised standard for the accreditation of PV training programmes and the certification of the participants. The programme is being developed in close co-operation with the PV industry in several regions of the world, in order to reach a consensus of agreement on its structure and organisation. The accredited training programmes will ultimately be recognised reciprocally in all regions.

5.2.3. System installation

Until very recently there were no standards or guidelines available for the installation of stand-alone PV systems. The quality of installation work has therefore varied considerably depending on the installers' knowledge, experience, and willingness to implement best practice. There is a PV GAP Recommended Standard on system installation. The South African Solar Home System Specification NRS-052 described above also gives a specification for installation of SHS. A Ugandan document has also been published recently, which describes quality installation of SAPV systems.

The installation of PV systems often determines whether systems function properly or not or, on a larger scale, whether a government or aid agency PV programme is a success or a failure. The messages given by such success or failure stories obviously have a very significant impact on the future of the PV market and PV industry. Similarly, potential large users or groups of users could be discouraged from using PV as a result of systems failing due to poor installation. Experience in other sectors shows that a bad reputation gained as a result of failing systems can destroy the confidence of potential clients and give a technology a bad name for years.

5.2.4. Commissioning tests

Commissioning tests, as well as commissioning procedures, are required to assure the user of the proper functioning of a PV system at the time of installation. These are different to measuring the performance of a system after some months or years of operation based on monitored data. They are important as they provide the user, owner or financier with proof that the system is operating correctly at the time of installation.

At present there are no commissioning tests in general use for SAPV systems. Instead, each installer must devise and conduct their own methods to ensure the system is operational. There is a method for on-site checking of the installed power of a PV array (IEC 61829), but none which extends to the entire PV system. Such tests would be an important component for the success of major funding programmes for SAPV systems in developing countries.

5.2.5. PV system monitoring

The most widely used guidelines for PV system monitoring are defined in the IEC standard IEC 61724 (see Annex 1). This outlines the required parameters to be measured for both 'global monitoring' (for systems of < 5 kWp) and 'analytical monitoring' (for larger systems and research projects). It also describes formats for presentation of data and formulae for the calculation of a 'Performance Ratio' by which the overall efficiency of similar systems can be compared, irrespective of the local climate data.

An alternative method of evaluating historical system performance of stand-alone PV systems is being implemented by Trama Tecnoambiental in Spain. This method has been devised following experience with evaluation of monitoring data from a large number of stand-alone and hybrid PV systems in Spain. The objectives are to provide information about the *quality of service* provided to the user, and to assess how successfully the user is operating the system and managing their energy needs; the *correct interaction*. It defines the use of a new performance parameter to achieve this: the Historical Battery Index, HBI. This type of monitoring may also be used in conjunction with the provision of a *performance guarantee* to the user / owner (see below).

Task 3 is currently developing a document which will outline suggested *performance indicators* for each category of SAPV and hybrid PV system. It will also make recommendations on how to make use of these indicators and categories to monitor and analyse data from SAPV systems. These guidelines will use Task 3 *Case Studies* to illustrate how to evaluate system performance with respect to other non-technical factors which also play an important role in determining the operation of a PV system.

5.2.6. Warranties and performance guarantees

Most manufacturers issue warranties for individual components of the SAPV system. As a rule, warranties for PV modules are ten years for 90% of the nominal rated power. Electronic components are more likely to have a one year warranty whilst batteries might have three years at the most.

Performance guarantees, which provide a contractual guarantee for the performance of the system as a whole, are provided by some SAPV system suppliers, but this is actually quite rare. Suppliers are often reluctant to provide such a guarantee, as this requires a dedicated monitoring system, in order to verify and assess the reasons for system failure. This in turn adds to the cost of the installed system.

However, many BOS components such as charge controllers and inverters now have on-board monitoring, which reduces the additional costs of monitoring. Furthermore, the data may be collected remotely, which eliminates travel time and expense. Such systems can, for example, provide data which indicates the poor utilisation of a battery. This enables the system supplier / O&M engineer to rectify a potential problem before it leads to system failure. In the long term, it can be seen that this type of monitoring strategy will reduce the cost of the installed system over its lifetime.

A typical performance guarantee might provide a 15 year energy service contract, which includes flawless operation of a system, replacement of any failed component within a certain timeframe, and a guaranteed minimum quantity of energy available per day in the worst case scenario.

5.2.7. Operation and maintenance

In order to ensure that an installed SAPV / hybrid system will provide a secure supply of energy, it is vital that procedures for the correct operation and maintenance of the system are in place. Some of the specifications detailed in Section 4.3 include descriptions of the information that should be included in an O&M manual. However, there are as yet no globally recognised guidelines for providing such a document.

There are various methods in use for system maintenance, depending on the circumstances. Some PV system / energy providers make regular visits, others stay in contact by telephone; in the worst case, there is no contact at all. A procedure which works well for one project may not be suitable for a different project. Any international guidelines formulated on this subject must be carefully defined according to system category and local conditions.

5.2.8. User involvement

Research and experience has shown that a PV system is less likely to fail in projects where the user has been actively involved in defining the system requirements, and has been able to play a part in the operation and maintenance of a PV system.

The involvement of the user in the operation and maintenance of a PV system should, however, be carefully managed. It is inevitable that, in most SAPV systems that supply power to people's residences, the inhabitant will attempt to operate or change the system. In order to minimise system failures, user manuals should be written which enable the user to understand the basic design and functions of the system.

The issue of user satisfaction is not immediately associated with improving the quality of installed PV systems. Certainly, one expects that a quality system will result in a satisfied user, but there is also an important relationship in the reverse direction, which is important for the long term successful operation of a PV system. The parameter of *user satisfaction* is routinely evaluated by the user association / energy operator SEBA, in order to provide feedback on the quality of the energy service provided.

6. CONCLUSIONS

There is a considerable amount of activity within the PV industry in the area of standards and QA for PV systems. Various documents have been published which are relevant to this subject. These include international standards from recognised standards committees; Best Practices from organisations such as the World Bank and IEA PVPS; and specifications for the evaluation of tenders to major aid-funded programmes.

Within IEC and CENELEC, standards covering individual components of stand-alone PV systems as well as standards covering system aspects are in preparation. PV GAP has published draft Recommended Standards which can be used until the official standards are published. As another matter of high priority, international standards which govern certification and accreditation procedures are being developed.

The development of a standard covering installation aspects of stand-alone PV systems is important, as poor installation can lead to system malfunctioning. PV GAP is presently reviewing such a document for inclusion in its range of Recommended Standards. This can have a significant impact, as the quality of installations can affect the success or failure of a large PV rural electrification programme.

A comprehensive set of standards for acceptance testing (commissioning) for stand-alone PV systems is required for use by large aid programmes initiated by the World Bank and other organisations. It is essential that an acceptable level of quality is ensured for systems installed under such programmes and for this reason standards for acceptance testing need to be developed.

Standards for stand-alone PV systems for professional ‘service’ applications, such as telecommunications, are also lacking, but are of lower priority. This is because there are no significant problems with the quality of these applications today.

7. GLOSSARY OF COMMONLY USED ACRONYMS

BOS	Balance of System: refers to components in a PV system other than the PV modules.
CB Scheme	Scheme of the IECEE for Mutual Recognition of Test Certificates for Electrical Equipment.
CB-FCS	Full Certification Scheme of the IECEE: an extension of the CB Scheme.
CD	Committee Draft. This draft is reviewed by the IEC Technical Committee. IEC terminology.
CDV	Committee Draft for Voting. This is circulated to all IEC member countries for voting. The National Committees review the CDV. Technical as well as editorial comments can be made. IEC terminology.
CEN	Comité Européen de Normalisation. European body which issues international standards in areas other than electrical engineering, electronics, or telecommunications.
CENELEC	European Committee for Electrotechnical Standardisation.
CIE	The International Commission on Illumination (Commission Internationale de L'éclairage). Organisation which publishes information on all aspects of lighting.
CLC/TC82	Technical Committee 82 of CENELEC, which deals with PV.
EDF	Electricité de France.
EN	Abbreviation designating a CENELEC standard.
EPIA	European Photovoltaic Industry Association.
ETSI	European Telecommunications Standards Institution. Body which deals with telecommunications standards on a European level.
FDIS	Final Draft International Standard. This is also circulated to all member countries for voting. IEC terminology.
GTZ	Gesellschaft für Technische Zusammenarbeit – German Corporation for International Co-operation.
IEC	International Electrotechnical Commission.
IECEE	IEC system for conformity testing and certification of

	electrotechnical equipment and components
IEEE	Institute of Electrical and Electronics Engineers. A US professional organisation which issues standards and codes of practice, some of which relate to PV.
ISO	International Organisation for Standardisation. International body which issues international standards in areas other than electrical engineering, electronics, or telecommunications.
ITU	International Telecommunication Union.
NREL	National Renewable Energy Laboratory of the USA.
NWP	New Work Item Proposal (also NWIP or NP). IEC terminology.
prEN	Designates a CENELEC pre-standard.
PV GAP	Global Approval Programme for Photovoltaics.
PV-UK	British Photovoltaic Association.
PWI	Potential New Work Item. IEC terminology.
QA	Quality Assurance.
SAPV	Stand-alone (off-grid) photovoltaics.
SHS	Solar home systems; for the purpose of this report defined as small single-home off-grid PV system to provide power mainly for lighting, sometimes also for radio, TV or other low-power appliances.
TC 82	Technical Committee 82 of the IEC, which focuses on PV.
UL	Underwriters Laboratory. A US organisation which issues safety regulations and carries out testing. In the US, electrical inspectors often refuse to accept products that have not been tested to UL specifications.
UNDP	United Nations Development Programme.
WD	Working Draft. IEC terminology.
WG	Working Group. Subgroup of IEC or CENELEC committees.

ANNEX 1: OVERVIEW OF EXISTING STANDARDS

General and systems standards relevant to SAPV

- IEC 61277 Ed. 1.0 - *Terrestrial photovoltaic (PV) power generating systems - General and guide.*

Gives an overview of terrestrial PV power generating systems and the functional elements of such systems. This standard is due to be withdrawn as it is considered to be no longer applicable.

- IEC 61836 TR2 Ed. 1.0 - *Solar photovoltaic energy systems - Terms and symbols.*

(Note: This is a Technical Report, not an IEC Standard). Gives definitions for terms and symbols used in IEC standards.

- IEC 61173 Ed. 1.0 *Overvoltage protection for photovoltaic (PV) power generating systems - Guide* (1995).

Gives guidance on the protection of overvoltage issues for both stand-alone and grid-connected photovoltaic power generating systems. Identifies sources of overvoltage hazard, including lightning and identifies the various types of protection.

- IEC 61194 Ed. 1.0 *Characteristic parameters of stand-alone photovoltaic (PV) systems* (1996).

Defines the major electrical, mechanical and environmental parameters for the description and performance analysis of stand-alone photovoltaic systems.

- IEC 61724 Ed. 1.0 *Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis* (1998).

Recommends procedures for the monitoring of energy-related photovoltaic (PV) system characteristics, and for the exchange and analysis of monitored data. The purpose is the assessment of the overall performance of PV systems.

- IEC 61725 Ed. 1.0 *Analytical expression for daily solar profiles.*

Provides an equation for analytically deriving a set of data points or curve for irradiance versus time of day for a synthetic solar day.

- IEC/TS 62257-1 Ed. 1.0 *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 1: General introduction to rural electrification.*

This technical specification introduces general considerations on rural electrification and the IEC 62257 series. This series intends to provide to different players involved in rural electrification projects specifications for the setting up of low voltage renewable energy and hybrid systems.

- IEC/PAS 62111 Ed. 1.0 *Specifications for the use of renewable energies in rural decentralised electrification*

Based on the French publication by EDF 'DRE Specifications'. Has status of a publicly available specification (PAS), and may also become an IEC standard in the future.

- ITU-D GAS 4 *(published by ITU; formerly CCITT-GAS 4) Primary sources of energy for the power supply of remote telecommunication systems.*

Publication of the ITU-D Sector (Development); Handbooks and Manuals. 1985. Study Group: GAS 4. This document contains a section on PV.

- AS 4509.1-1999/Amdt 1-2000 *Stand-alone Power Systems, Part 1. Safety Requirements*

This Standard sets out safety requirements for stand-alone power systems used for the supply of extra-low and low voltage electric power to a single residence or a small group of residences or buildings and associated items, with energy storage at extra-low voltage. Equipment up to, and including, the system output terminals is covered by this Standard.

- AS 4509.2-2002 *Stand-alone power systems - Part 2: System design guidelines*

This Standard sets out guidelines for the design of stand-alone power systems with energy storage at extra-low voltage used for the supply of extra-low and low voltage electric power in a domestic situation. Equipment up to the system output terminals is covered. The principles in this Standard can be applied to other systems including commercial and industrial applications.

- AS 4509.3-1999 /Amdt 1-2000 *Stand-alone Power Systems, Part 3. Installation & Maintenance*

This Standard sets out requirements for the installation and maintenance of stand-alone power systems used for the supply of extra-low and low voltage electric power to a single residence or a small group of residences or buildings and associated items, with energy storage at extra-low voltage. Equipment up to, and including, the system output terminals is covered by this Standard.

- NREL/TP-520-25077 *Interim Test Methods and Procedures for Determining the Performance of Small Photovoltaic Systems.* July 1998.

Covers small grid-connected and stand-alone PV systems up to 5kW. The methodology covers complete system testing outdoors under prevailing conditions.

- NREL/TP-520-27031: *Procedures for Determining the Performance of Stand-Alone Photovoltaic Systems*

This document provides the procedures for determining the performance of stand-alone PV systems. The procedures in this document provide a common approach for evaluation whether a given PV system is suitable to perform the function for which it was designed and manufactured to accomplish, and whether it will provide adequate power to run the load.

- JIS-C8905 *General Rules for Stand-alone Photovoltaic Power Generating Systems* (Japan, 1996)

Contents include scope (by output power and voltage), definition of terms, criteria of installation site condition (indoor temperature, outdoor temperature, altitude, etc.), classification of system (with battery or without battery, DC or AC, common load or specific load, type of cells etc.), terms and symbols of system classification (such as SA-WBA-DC-SP(Si-a) etc.), standard of output power condition for common load.

Contents also cover performance: insulation resistance; breakdown voltage; output power of PV array; output power of PV system and maximum expected consecutive days of cloudy weather; operational characteristics of PV system.

They include PV system components, structural design of PV system, terminals, Performance test methods, inspection of system installation, and labelling of system (with type of PV system, output power, current, frequency, battery capacity and voltage, manufacturer’s name, manufacturing date etc.)

- TR C D005 *Design Guide on electrical circuit for photovoltaic array* (1997, Japan)

Japanese technical report which gives guidelines on electrical circuits for PV arrays.

- TR C D006 *Design Guide on structures for photovoltaic array* (1997, Japan)

Japanese technical report which gives guidelines on structures for PV arrays.

- IEEE 928-1986 (R1991) *IEEE Recommended Criteria for Terrestrial Photovoltaic Power Systems*

The American National Standard (ANSI) IEEE Recommended Criteria for terrestrial photovoltaic power systems.

Standards for PV Modules

- IEC 60891 Ed. 1.0 - *Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices (with Amendment 1).*

Gives procedures that should be followed for temperature and irradiance corrections to the measured I-V characteristics of crystalline silicon photovoltaic devices.

Includes the determination of temperature coefficients, internal series resistance and curve correction factor.

- IEC 60904-1 Ed. 1.0 - *Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics*.

Describes measurement procedures for current-voltage characteristics of crystalline silicon photovoltaic devices in natural or simulated sunlight. These procedures are applicable to a single solar cell, a sub-assembly of solar cells, or a flat module.

- IEC 60904-2 Ed. 1.0 - *Photovoltaic devices. Part 2: Requirements for reference solar cells (with Amendment 1).*

Gives requirements for the classification, selection, packaging, marking, calibration and care of reference solar cells.

- IEC 60904-3 Ed. 1.0 - *Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*.

Applies to the following crystalline silicon photovoltaic devices for terrestrial applications: single solar cells with or without protective cover, sub-assemblies of solar cells, and flat modules.

- IEC 60904-5 Ed. 1.0 - *Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method.*

Describes the preferred method for determining the equivalent cell temperature of PV devices for the purposes of comparing their thermal characteristics, determining NOCT (nominal operating cell temperature) and translating measured I-V characteristics.

- IEC 60904-6 Ed. 1.0 - *Photovoltaic devices - Part 6: Requirements for reference solar modules (with Amendment 1).*

Gives requirements for the selection, packaging, calibration, marking, and care of reference solar modules. It is intended to supplement IEC 904-2.

- IEC 60904-7 Ed. 2.0 - *Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device.*

Describes the procedure for determining the error introduced in the testing of a photovoltaic device caused by the interaction of the mismatch between the spectral responses of the test specimen and the reference device, and the mismatch between the test spectrum and the reference spectrum.

- IEC 60904-8 Ed. 2.0 - *Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device.*

Gives guidance for the measurement of the relative spectral response of both linear and non-linear photovoltaic devices. This is only applicable to single-junction devices.

- IEC 60904-9 Ed. 1.0 - *Photovoltaic devices - Part 9: Solar simulator performance requirements.*

Gives requirements for solar simulators used for indoor testing of terrestrial flat plate (non-concentrating) photovoltaic devices in conjunction with a spectrally matched reference device. (Note: an Amendment to IEC 904-9 to take into account thin-film silicon is being worked on - see below).

- IEC 60904-10 Ed. 1.0 - *Photovoltaic devices - Part 10: Methods of linearity measurement.*

Describes procedures used to determine the degree of linearity of any photovoltaic device parameter with respect to a test parameter.

- IEC 61215 Ed. 1.0 - *Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval.*

Lays down requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long-term operation in general open-air climates, as defined in IEC 721-2-1. Applies only to crystalline silicon types.

- IEC 61345 Ed. 1.0 - *UV test for photovoltaic (PV) modules.*

Determines the ability of a photovoltaic module to withstand exposure to ultra-violet (UV) radiation from 280 nm to 400 nm.

- IEC 61646 Ed. 1.0 - *Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval.*

Lays down requirements for the design qualification and type approval of terrestrial thin-film photovoltaic modules suitable for long-term operation in moderate open-air climates.

- IEC 61701 Ed. 1.0 - *Salt mist corrosion testing of photovoltaic (PV) modules.*

Determines the resistance of the module to corrosion from salt mist.

- IEC 61721 Ed. 1.0 - *Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test).*

Determines the susceptibility of a module to accidental impact damage.

- IEC 61829 Ed. 1.0 - *Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics*.

Describes procedures for on-site measurement of crystalline silicon photovoltaic (PV) array characteristics and for extrapolating these data to Standard Test Conditions (STC) or other selected temperatures and irradiance values.

- EN 50380: *Datasheet and nameplate information for photovoltaic modules*

European standard specifying the data to be provided by PV module manufacturers, in order to characterise the module.

- AS 2915-1987 *Solar photovoltaic modules - Performance requirements*

Specifies performance requirements for terrestrial flat-plate solar photovoltaic modules and gives methods of measurement of module performance and environmental tests. Safety requirements are also specified. The aim is to establish minimum performance and life expectancy of ten years in the field.

- UL1703: *Flat-Plate Photovoltaic Modules and Panels*

Standard that gives the construction and performance requirements as well as test procedure for safety approval of PV modules.

- DIN 40025 *(1997-05) Datenblatt- und Typschildangaben für Photovoltaik-Module (Data sheet and nameplate information for photovoltaic modules)*

Proforma specifying the data to be provided by PV module manufacturers, in order to characterise the module.

- CSA F380*: Photovoltaic modules*

Canadian standard which covers the construction, performance requirements and marking of PV modules.

- JIS-C8918 *Crystalline solar PV module* (Japan, 1989)

Japanese standard on crystalline silicon PV module physical design , structure and performance.

- JIS-C8939 *Amorphous solar PV module* (Japan, 1995)

Japanese standard on amorphous silicon PV module physical design , structure and performance.

- JIS-C8940 *Outdoor Measuring Method of Output Power for Amorphous Solar Cells and Modules* (Japan, 1995)

Japanese standard which describes the outdoor measuring methods for power output of amorphous solar cells and modules.

- JIS-C8951 *General Rules for Photovoltaic Array* (Japan, 1996*)*

Japanese standard which describes the general requirements of a photovoltaic array.

- JIS-C8952 *Indication of Photovoltaic Array Performance* (Japan, 1996)

Japanese standard which describes a method of giving an estimation of PV array performance.

- JIS-C8953 *On-site Measurements of Photovoltaic Array I-V Characteristics* (Japan, 1993, will be revised soon)

Japanese standard which describes on-site measurement procedures for determining PV array I-V characteristics.

Standards for Inverters and Charge Controllers

- IEC 61683 Ed. 1.0 *Photovoltaic systems - Power conditioners - Procedure for measuring efficiency*

Describes guidelines for measuring the efficiency of power conditioners used in stand-alone and utility-interactive photovoltaic systems, where the output of the power conditioner is a stable a.c. voltage of constant frequency or a stable d.c. voltage.

- JIS-C8980 *Power Conditioner for Small Photovoltaic Power Generating System* (Japan, 1997)

Japanese standard which describes the requirements of power conditioners in small photovoltaic systems.

- JIS-C8962 *Testing Procedure of Power Conditioner for Small Photovoltaic Power Generating Systems* (Japan, 1997)

Japanese standard which describes the testing procedure for power conditioners in small photovoltaic systems.

- UL1741: *Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems.*

Standard that gives the construction and performance requirements as well as test procedure for safety approval of inverters, charge controllers and AC modules.

Standards for Batteries

- IEC 61427 *Ed. 1.0 b Secondary cells and batteries for solar photovoltaic energy systems - General requirements and methods of test*

Prepared by the Joint TC21/TC82 Working Group. Gives general information relating to the requirements of the secondary batteries used in photovoltaic (PV) solar systems and to the typical methods of test used for the verification of battery performances. Describes capacity, cycle endurance and mechanical endurance tests. This Standard does not include specific information relating to battery sizing, method of charge or PV system design.

- IEC 60095-1 *Ed. 6.0 Lead-acid starter batteries. Part 1: General requirements and methods of test*

Applies to lead-acid batteries used for starting, lighting and ignition of passenger automobiles and light commercial vehicles with a nominal voltage of 12 V, fastened to the vehicles by means of ledges on the long sides of the battery case. Defines international specifications for several groups of batteries according to the general type of application and the climatic conditions.

- IEC 60095-2 *Ed. 3.0; (including amendments 1 and 2). Lead-acid starter batteries. Part 2: Dimensions of batteries and dimensions and marking of terminals*

Applies to lead-acid batteries used for starting, lighting and ignition of passenger automobiles and light commercial vehicles with a nominal voltage of 12 V, fastened to the vehicles by means of ledges on the long sides of the battery case. Specifies: the main dimensions of starter batteries of four standard series; the location of the positive and negative terminals with respect to the fastening system; the dimensions of tapered terminals of starter batteries; the marking of the polarity.

- IEC 60095-4 *Ed. 1.0; (including amendment 1). Lead-acid starter batteries. Part 4: Dimensions of batteries for heavy trucks*

Applies to lead-acid batteries used for starting, lighting and igniting of heavy trucks.

- IEC 60254-1 *Ed. 3.0 Lead-acid traction batteries - Part 1: General requirements and methods of test*

Is applicable to lead-acid traction batteries used as power sources for electric propulsion. Clauses 1 to 5 are applicable to all traction battery applications which include road vehicles, locomotives, industrial trucks and mechanical handling equipment. Clause 6 offers a series of tests which may be used specifically to test batteries developed for use in vehicles such as light passenger vehicles, motor cycles, light commercial vehicles, etc.

- IEC 60254-*2 Ed. 3.1; (including amendment 1). Lead-acid traction batteries - Part 2: Dimensions of cells and terminals and marking of polarity on cells*

Specifies: the maximum external dimensions of traction battery cells; the form of the marking of traction battery cell polarity and dimensions of corresponding symbols; the basic dimensions of some commonly used traction battery terminals.

- IEC 60623 *Ed. 3.0 b Vented nickel-cadmium prismatic rechargeable single cells*

Specifies tests and requirements for vented nickel-cadmium prismatic secondary single cells.

- IEC 60896-11 *Ed. 1.0 Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of test.*

Applies to lead-acid cells and batteries which are designed for service in a fixed location (i.e. not habitually to be moved from place to place) and which are permanently connected to the load and to the d.c. power supply. Batteries operating in such applications are called 'stationary batteries'. Any type or construction of lead-acid battery may be used for stationary battery applications. Part 11 of the standard is applicable to vented types only.

- IEC 60896-21 *Ed. 1.0 Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test*

Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (i.e. permanently connected to a load and to a d.c. power supply) and in a static location (i.e. not generally intended to be moved from place to place). Specifies methods of test for all types and construction of valve regulated stationary lead acid cells and monobloc batteries used in standby power applications.

- IEC 60896-22 *Ed. 1.0 Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements*

Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (i.e. permanently connected to a load and to a d.c. power supply) and in a static location (i.e. not generally intended to be moved from place to place). The objective of this part of IEC 60896 is to assist the specifier in the understanding of the purpose of each test contained within IEC 60896-21 and provide guidance on a suitable requirement that will result in the battery meeting the needs of a particular industry application and operational condition.

- IEC 61044 *Ed. 2.0 Opportunity-charging of lead-acid traction batteries*

This Technical Report covers the 'opportunity-charging' of lead-acid traction batteries, i.e., the use of free time during a working period to top up the charge and thus extend the working day of a battery whilst avoiding excessive discharge. It has the status of a technical report.

- IEC 61056-1 *Ed. 2.0 Portable lead-acid cells and batteries (Valve regulated types) - Part 1: General requirements, functional characteristics - Methods of test*

This standard is applicable to lead-acid batteries of the valve regulated type for cyclic and standby application with the rated capacity not exceeding 25 Ah.

- IEC 61056-2 *Ed. 2.0 Portable lead-acid cells and batteries (Valve regulated types) - Part 2: Dimensions, terminals and marking*

Dimensions applicable to lead-acid batteries of the valve regulated type for cyclic and standby application with the rated capacity not exceeding 25 Ah.

- IEC/TR 61056-3 *Ed. 1.0 Portable lead-acid cells and batteries (Valve-regulated types) - Part 3: Safety recommendations for use in electric appliances*

Safety recommendations applicable to lead-acid batteries of the valve regulated type for cyclic and standby application with the rated capacity not exceeding 25 Ah.

- IEC 61429 *Ed. 1.0 Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135*

This International Standard defines the conditions of utilisation of the recycling symbol of the International Organisation for Standardisation (ISO) associated with the chemical symbols indicating the electrochemical system of the battery. This standard applies to lead-acid batteries (Pb) and nickel-cadmium batteries (Ni-Cd).

- IEC/TR 61430 *Ed. 1.0 Secondary cells and batteries - Test methods for checking the performance of devices designed for reducing explosion hazards - Lead-acid starter batteries*

Gives guidance on procedures for testing the effectiveness of devices which are used to reduce the hazards of an explosion, together with the protective measures to be taken.

- IEC/TR 61431 *Ed. 1.0 Guide for the use of monitor systems for lead-acid traction batteries*

This is an informative document covering the broadest aspects of automatic monitor systems as they apply to traction battery applications. The subject of the guide covers those monitor characteristics and features which need to be controlled, though not necessarily currently available. In addition it accommodates those characteristics which are measurable and provides interpretations of accuracy and reliability of the information generated. This publication has the status of a Technical Report – type 3.

- EN 50272 *Safety Requirements for Secondary Batteries and Battery Installations Part 2: Stationary Batteries*

European standard which describes safety requirements for stationary secondary batteries.

- JIS-C8971 *Measuring Procedure of residual capacity for Lead Acid Battery in Photovoltaic System* (Japan, 1993)

Japanese standard which describes the measurement procedure for Lead Acid battery residual capacity in photovoltaic systems.

- JIS-C8972 *Testing Procedure of Long Discharge Rate Lead-Acid Batteries for Photovoltaic Systems (*Japan, 1997)

Japanese standard which describes the testing procedure for Lead Acid battery which have been discharged over a long period in photovoltaic systems.

- IEEE 937-1987*(R1993) IEEE Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems*

Design considerations and procedures for storage, location, mounting, ventilation, assembly and maintenance of lead-acid storage batteries for photovoltaic systems.

- *IEEE 1013-1990 IEEE Recommended Practice for Sizing Lead-Acid Batteries for Photovoltaic (PV) Systems (ANSI)*

Recommends methods for sizing both vented and valve regulated lead-acid batteries for stand-alone PV systems.

- *IEEE 1144-1996 IEEE Recommended Practice for Sizing of Industrial Nickel-Cadmium Batteries for Photovoltaic (PV) Systems*

A method for sizing nickel cadmium batteries used in residential, commercial and industrial PV systems.

- *IEEE 1145-1990 IEEE Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems*

Recommended Practice for installation and maintenance of nickel cadmium batteries for PV systems, includes safety guidelines.

- NF C 58-510 (1992) *Batteries d'accumulateurs au plomb destinées au stockage de l'energie électrique d'origine photovoltaïque (Lead-acid secondary batteries for storing electrical energy generated by a photovoltaic system).*

This French standard comprises a glossary defining the main parameters, a description of the battery operational characteristics and test methods - including accuracy of measurement instruments - on faradic efficiency, cycling and overcharge capacity, and mechanical endurance.

- NF F 64-328 and NF F 48-515: *Lead-acid secondary traction batteries for railway materials.*

French standard providing definition of cycling procedures for lead-acid secondary traction batteries.

- DIN 43539, SAE J573: *Lead-acid secondary SLI batteries.*

German standard giving definition of cycling procedures for lead-acid secondary SLI (starting, lighting and ignition) batteries.

- AS 4086.1, 1993 *Secondary batteries for use with stand-alone power systems. - General Requirements.*

This Australian standard specifies requirements for secondary batteries for use with stand-alone power systems, supplied with power from one or a combination of the following sources: a photovoltaic array, a wind generator, a water generator or a diesel generator. This Standard specifies requirements for all types of batteries including lead-acid and nickel-cadmium and covers both vented and sealed cells. The Standard includes tests designed to verify the capacity, efficiency and life of batteries (Appendices A to I).

- AS 4086.2, 1997 *Secondary batteries for use with stand-alone power systems - Installation & Maintenance*

Specifies requirements for the installation and maintenance of secondary batteries installed in stand-alone power systems, i.e. power systems that are not connected to the power distribution system of an electricity supply authority. It applies to the installation of all types of batteries.

- AS 3011.1 *Electrical installations - Secondary batteries installed in buildings - Vented cells*

This Standard sets out requirements for the installation of vented secondary batteries with a nominal voltage exceeding 24 V and a capacity exceeding 10 Ah at the 1 h rate of discharge, permanently installed in or on buildings, structures or premises to ensure safety from fire and electric shock.

- AS 3011.2 *Electrical installations - Secondary batteries installed in buildings - Sealed cells*

This Standard sets out requirements for the installation of sealed secondary batteries with a nominal voltage exceeding 24 V and a capacity exceeding 10 Ah at the 1 h rate of discharge, permanently installed in or on buildings, structures or premises to ensure safety from fire and electric shock.

- AS 2676.1 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Vented cells

This Standard sets out recommended practices for the installation, maintenance, testing and replacement of vented secondary batteries permanently installed in or on buildings. It also provides guidance to determine when batteries should be replaced.

This Standard covers secondary batteries with a nominal voltage of 24 V or greater, and a capacity exceeding 10 Ah at the 1 h rate and includes batteries comprising vented lead-acid cells and alkaline batteries comprising vented cells (such as nickel-cadmium cells).

This Standard covers requirements for components of the d.c. system of which the battery is a part, where these components comprise an essential part of the d.c. system.

- AS 2676.2 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Sealed cells

This Standard sets out recommended practices for the installation, maintenance, testing and replacement of sealed secondary batteries (either valve-regulated or gastight) located in or on buildings. It also provides guidance to determine when batteries should be replaced.

This Standard covers secondary batteries with a nominal voltage of 24 V or greater, and a capacity exceeding 10 A.h at the 1 h rate and includes batteries comprising lead-acid cells and alkaline cells (such as nickel-cadmium cells).

This Standard covers requirements for components of the d.c. system of which the battery is a part, where these components comprise an essential part of the d.c. system.

- CSA F382: *Characterisation of Storage Batteries for Photovoltaic Systems*

This Canadian standard gives recommendations on specifying, testing and reporting battery performances. It is currently being revised and its re-acceptance is pending.

Standards for PV Pumping Systems

- IEC 61702 Ed. 1.0 *Rating of direct coupled photovoltaic (PV) pumping systems*.

Defines predicted short-term characteristics (instantaneous and for a typical daily period) of direct coupled photovoltaic (PV) water pumping systems.

Lighting Standards

- IEC 60081:1997 *Double-capped fluorescent lamps. Performance specifications.*

Characteristics, technical requirements and the test methods to be used for type, batch or whole production testing.

- IEC 60901:1996 *Specification for single-capped fluorescent lamps*. *Performance specifications.*
- IEC 60921 Ed. 1.0 *Specification for ballasts for tubular fluorescent lamps. Performance requirements. (With Amendments 1 and 2 and Corrigendum 1).*

Specifies performance requirements for ballasts excluding resistance types for use on a.c. supplies up to 1,000 V at 50 Hz or 60 Hz, associated with tubular fluorescent lamps with preheated cathodes operated with or without a starter switch and having rated wattages, dimensions and characteristics as specified in IEC 60081. It complies with complete ballasts and their component parts such as resistors, transformers and capacitors. Supersedes IEC 60082.

- IEC 60923 Ed. 2.1 *Auxiliaries for lamps. Ballasts for discharge lamps (excluding tubular fluorescent lamps). Performance requirements.*

Specifies performance requirements for ballasts for discharge lamps such as high-pressure mercury vapour, low-pressure sodium vapour, high-pressure sodium and metal halide lamps. Each section details specific requirements for a particular type of ballast. Covers inductive type ballasts for use on a.c. supplies up to 1 000 V at 50 Hz or 60 Hz associated with discharge lamps, having rated wattage, dimensions and characteristics as specified in the relevant IEC lamp standards.

- IEC 60925 Ed. 1.2 *DC supplied electronic ballasts for tubular fluorescent lamps - Performance requirements*

Specifies general performance requirements for electronic ballasts for use on d.c. supplies having rated voltages not exceeding 250 V associated with tubular fluorescent lamps.

- IEC 60927 Ed. 2.1 *Auxiliaries for lamps - Starting devices (other than glow starters) - Performance requirements.*

Specifies performance requirements for starting devices (starters and ignitors) for tubular fluorescent and other discharge lamps for use on a.c. supplies up to 1,000 V at 50 Hz or 60 Hz which produce starting pulses not greater than 5 kV.

- IEC 60929 Ed. 1.0*AC-supplied electronic ballasts for tubular fluorescent lamps - Performance requirements.*

Specifies performance requirements for electronic ballasts for use on a.c. supplies up to 1,000 V at 50 Hz or 60 Hz with operating frequencies deviating from the supply frequency, associated with tubular fluorescent lamps as specified in IEC 60081 and IEC 60901 and other tubular fluorescent lamps for high frequency operation.

- IEC 61195 Ed. 2.0 *Double-capped fluorescent lamps - Safety specifications.*

For lamps for general lighting purposes of all groups having Fa6, Fa8, G5, G13 and R17d caps.

Double-capped fluorescent lamps - Safety specifications

Specifies the safety requirements for double-capped fluorescent lamps for general lighting purposes of all groups having Fa6, Fa8, G5, G13 and R17d caps. Also specifies the method a manufacturer should use to show compliance with the requirements of this standard.

- BS EN 61199:1994 *Single-capped fluorescent lamps. Safety specifications.*

Specifies requirements for a range of lamps operated on a.c. supplies.

IEC 61347-1 (2003-11) Ed. 1.1 (Amendment 1 is incorporated into Ed. 1.1)

Lamp controlgear - Part 1: General and safety requirements

This part of IEC 61347 specifies general and safety requirements for lamp controlgear for use on d.c. supplies up to 250 V and/or a.c. supplies up to 1 000 V at 50 Hz or 60 Hz. This standard also covers lamp controlgear for lamps which are not yet standardized. Tests dealt with in this standard are type tests. Requirements for testing individual lamp controlgear during production are not included.

This part 1 is to be used in conjunction with the appropriate part 2, which contains clauses to supplement or modify the corresponding clauses in part 1, to provide the relevant requirements for each type of product.

This first edition of IEC 61347-1, together with parts 1 to 9 of IEC 61347-2, cancels and replaces IEC 60920, IEC 60922, IEC 60924, IEC 60926, IEC 60928 and IEC 61046, and constitute a minor revision.

The relationship between the parts that make up IEC 61347-2 and the IEC standards they replace is detailed as follows: IEC 61347-2-1 replaces IEC 60926 IEC 61347-2-2 replaces IEC 61046 IEC 61347-2-3 replaces IEC 60928 IEC 61347-2-4 replaces IEC 60924, Section 3 IEC 61347-2-5 replaces IEC 60924, Section 4 IEC 61347-2-6 replaces IEC 60924, Section 5 IEC 61347-2-7 replaces IEC 60924, Section 6 IEC 61347-2-8 replaces IEC 60920 IEC 61347-2-9 replaces IEC 60922.

IEC 61347-2-8 (2000-10) Lamp controlgear - Part 2-8: Particular requirements for ballasts for fluorescent lamps

This part of IEC 61347 specifies safety requirements for ballasts, excluding resistance types, for use on a.c. supplies up to 1,000 V at 50 Hz or 60 Hz, associated with fluorescent lamps with or without pre-heated cathodes operated with or without a starter or starting device and having rated wattages, dimensions and characteristics as specified in IEC 60081 and 60901.

IEC 61347-2-11 Ed.1.0 Lamp controlgear - Part 2-11: Particular requirements for miscellaneous electronic circuits used with luminaires.

IEC 61347-2-11 represents an editorial review of IEC 60920. It specifies general and safety requirements for miscellaneous electronic circuits used with luminaires for use on a.c. supplies up to 1,000 V at 50 Hz or 60 Hz and/or d.c. supplies up to 250 V. This part does not apply to circuits or devices for which specific IEC standards are published.

- BS 1853: Part 2:1995 *Tubular fluorescent lamps for general lighting service.*

Specification for lamps used in the United Kingdom not included in BS EN 60081, BS EN 60901, BS EN 61195 and BS EN 61199 (see top). Characteristics, technical requirements, test methods for type, batch or whole production testing.

ANNEX 2: OVERVIEW OF STANDARDS UNDER DEVELOPMENT

Draft PV Standards Relevant to SAPV (General / Systems)

- IEC 61836 TR Ed. 2.0 - *Solar photovoltaic energy systems - Terms and symbols.*

Revision of the existing standard IEC 61836. Status: Potential new work item.

- IEC 62124 Ed. 1.0: *Photovoltaic (PV) stand-alone systems - Design verification*

Status: Final Draft International Standard. Publication expected in 2004.

This is also a CENELEC draft standard (prEN 62124). CENELEC will await IEC results; no CENELEC work is considered necessary.

- IEC 62257-3 TS Ed. 1.0 *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 3: Project development and management.*

Status: Circulated technical specification.

- IEC 62257-4 TS Ed. 1.0 *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 4 : System selection and design.*

Status: Committee draft.

- IEC 62257-5 TS Ed. 1.0 *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 5: Safety rules: Protection against electrical hazards.*

Status: Committee draft.

- IEC 62257-6 TS Ed. 1.0 *Recommendations for small renewable energy and hybrid systems for rural electrification Part 6: Acceptance, operation, maintenance and replacement.*

Status: Committee draft.

- IEC PWI 82-1 Ed. 1.0 *Photovoltaic electricity storage systems*.

Status: Potential new work item (since 1992).

- JIS*:* Draft *Electric Safety Standards of Photovoltaic Power Generating Systems for Houses*

Draft Japanese standard listing electrical safety standards for PV systems installed on domestic properties, undergoing review.

- JIS: Draft *Structural Design and Installation of Rooftop Photovoltaic Arrays*

Draft Japanese standard on structural design and installation procedures for PV systems installed on domestic properties, undergoing review.

Draft Standards for PV Modules

- IEC 60904-1 Ed. 2.0 *Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics*

Revision of the existing standard IEC 60904-1. Status: First Committee Draft.

- IEC 60904-3 Ed. 2.0 *Photovoltaic Devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

Revision of the existing standard IEC 60904-3. Status: First Committee Draft.

- IEC 60904-4 Ed. 1.0 *Photovoltaic devices - Part 4: Procedures for establishing the traceability of the calibration of photovoltaic reference devices*

Status: Approved New Work. First Committee Draft expected during 2004.

- IEC 61215 Ed. 2.0 *Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval*

Revision of the existing standard IEC 61215. Status: To be circulated as Final Draft International Standard.

This is also a CENELEC draft standard (prEN 61215). CENELEC will await IEC results; no CENELEC work is considered necessary.

- IEC 61730-1 Ed. 1.0 *Photovoltaic module safety qualification - Part 1: requirements for construction*.

Status: Final Draft International Standard. To be published in 2004.

This is also a CENELEC draft standard (prEN 61730-1).

- IEC 61730-2 Ed. 1.0 *Photovoltaic module safety qualification - Part 1: requirements for testing*.

Status: Final Draft International Standard. To be published in 2004.

This is also a CENELEC draft standard (prEN 61730-2).

- IEC 61853 Ed. 1.0 *Performance testing and energy rating of terrestrial photovoltaic (PV) modules*.

Status: Approved New Work (since 2001).

- IEC 62108 Ed. 1.0 *Concentrator photovoltaic (PV) receivers and modules - Design qualification and type approval.*

Status: Potential new work item.

- IEC 62145 Ed 1.0 *Crystalline silicon terrestrial photovoltaic (PV) modules - Blank detail specification*

Status: Potential new work item.

- prEN 50xxx *Safety class definition for photovoltaic modules.*

Status: New work item.

- prEN 50xxx *Norm sizes of solar modules.*

Status: New work item.

Draft Standards for Inverters and Charge Controllers

- IEC 62093 Ed. 1.0 *Balance-of-system components for photovoltiac systems - Design qualification natural environments*.

Status: Draft International Standard.

This is also a CENELEC draft standard (prEN 62093). CENELEC will await IEC results; no CENELEC work is considered necessary.

- IEC 62109-1 Ed. 1.0 *Safety of power converters for use in photovoltaic power systems - Part 1: General requirements.*

Status: Committee draft.

- IEC 62109-2 Ed. 1.0 *Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters.*

Status: Committee draft.

- IEC 62109-3 Ed. 1.0 *Electrical safety of static inverters and charge controllers for use in photovoltaic (PV) power systems - Part 3: Controllers.*

Status: Approved new work.

- Draft prEN 50xxx *Inverter systems for photovoltaic systems - Grid and stand-alone.*

Status: Draft in preparation. This standard is to be developed as a European standard taking European market needs into account. It will be available faster than IEC 62109.

Draft standards for PV Pumping Systems

- 62253 Ed. 1.0 *Direct coupled photovoltaic pumping systems - Design qualification and type approval.*

Status: Potential new work item.

ANNEX 3: JAPANESE STANDARDS AND CORRESPONDING IEC STANDARDS

JIS			IEC		
JIS C 8960	1997	Glossary of terms for photovoltaic power generation	IEC 61836	1997	Solar photovoltaic energy systems - Terms and symbols
JIS C 8905	1993	General rules for stand-alone photovoltaic power generating system			
JIS C 8906	1993	Measuring procedure of photovoltaic system performance	IEC 61724	1998	Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
JIS C 8951	1996	General rules for photovoltaic array			
JIS C 8952	1996	Indication of photovoltaic array performance			
JIS C 8953	1993	On-site measurements of photovoltaic array I-V characteristics			
TR C 0005	1997	Design guide on electrical circuit for photovoltaic array			
TR C 0006	1997	Design guide on structures for photovoltaic array			
JIS C 8980	1997	Power conditioner for small photovoltaic power generating system			
JIS C 8961	1993	Measuring procedure of power conditioner efficiency for photovoltaic systems	Draft IEC 61683		Procedure for measuring the efficiency of power conditioners used in photovoltaic systems
JIS C 8962	1997	Testing procedure of power conditioner for small photovoltaic power generating systems			
JIS C 8971	1993	Measuring procedure of residual capacity for lead acid battery in photovoltaic system			
JIS C 8972	1997	Testing procedure of long discharge rate lead-acid batteries for photovoltaic systems			
JIS C 8911	1989	Secondary Reference Crystalline Solar Cells	IEC 60904-2	1989	Requirements for reference solar cells
			IEC 60904-3	1989	Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
			Draft IEC 1798		Linearity measurement methods
JIS C 8912	1989	Solar Simulators Used in Measuring Crystalline Solar Cells and Modules	IEC 60904-9	1995	Solar simulator performance requirements

JIS C 8913	1989	Measuring Method of Output Power for Crystalline Solar Cells	IEC 60904-1	1987	Measurement of photovoltaic current-voltage characteristic
JIS C 8915	1989	Measuring Method of Spectral Response for Crystalline Solar Cells	IEC 60904-8	1995	Guidance for the measurement of spectral response of a photovoltaic (PV) device
JIS C 8916	1989	Temperature Coefficient Measuring Methods for Crystalline Solar Cells and Modules	IEC 61215	1993	Crystalline silicon terrestrial Photovoltaic (PV) modules - Design qualification and type approval
JIS C 8914	1989	Measuring Method of Output Power for Crystalline Solar Cell Modules	IEC 60891	1987	Procedure for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
JIS C 8917	1989	Environmental and Endurance Test Methods for Crystalline Solar Cell Modules	IEC 61215 IEC 61701	1993 1995	Crystalline silicon terrestrial Photovoltaic (PV) modules - Design qualification and type approval Salt mist corrosion testing of PV modules
JIS C 8918	1989	Crystalline Solar Cell Module			
JIS C 8919	1995	Outdoor measuring method of output power for crystalline solar cells and modules	IEC 60891	1987	Procedure for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
			IEC 60904-2	1989	Requirements for reference solar cells
JIS C 8931	1995	Secondary reference amorphous solar cells	IEC 60904-3	1989	Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
JIS C 8932	1995	Secondary reference amorphous solar sub-modules	IEC 60904-6	1994	Requirements for reference solar modules
JIS C 8933	1995	Solar simulators for amorphous solar cells and modules	IEC 60904-9	1995	Solar simulator performance requirements
JIS C 8934	1995	Measuring method of output power for amorphous solar cells	IEC 60891	1987	Procedure for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
JIS C 8937	1995	Temperature coefficient measuring methods of output voltage and output current for amorphous solar cells and modules	IEC 61215	1993	Crystalline silicon terrestrial Photovoltaic (PV) modules - Design qualification and type approval
JIS C 8936	1995	Measuring methods of spectral response for amorphous solar cells and modules	IEC 60904-8	1995	Guidance for the measurement of spectral response of a photovoltaic (PV) device
JIS C 8935	1995	Measuring method of output power for amorphous solar modules	IEC 60891	1987	Procedure for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
JIS C 8938	1995	Environmental and endurance test methods for amorphous solar cell modules	IEC 61646	1997	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval.
JIS C 8939	1995	Amorphous solar PV modules			
JIS C 8940	1995	Outdoor measuring method of output power for amorphous solar cells and modules			