APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Adoption of Renewable Energy Standards
Phase II

Asia-Pacific
Economic Cooperation

APEC Energy Working Group

Expert Group on New and Renewable Energy Technologies

Prepared by
Institute for Sustainable Power Inc

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1.0 Introduction

This final report provides an overview of the activities undertaken in this project; summarizes the work undertaken in Phase 7 and includes the action plan and an alternative action developed for harmonization of the three prioritized standards.

Phases 1 involved a review of the action plan developed in the previous project EWG/012002T. This recommended the development of an APEC Standards Secretariat to oversee the harmonization of renewable energy standards. This work was undertaken by the project manager and completed by September 2005.

Phase 2 required the prioritizing of the standards that required harmonization and selecting the top three. A meeting of the project team was conducted in Shanghai in October 2005 and at this meeting it was concluded that the three priority areas were:

- Solar Water Heaters (manufacture and installation)
- Installation of PV Grid Connect Systems
- Installation of Stand Alone Power Systems

Phase 3 required the formation of three committees for each of the three priority areas. This phase was difficult because people who are members of standards committees within their own member economies or internationally are typically volunteers and therefore often do not have very much free time for other committees. This phase also raised some questions from potential committee members on why harmonize only in APEC while a number APEC member economies (e.g. Australia, Canada, China, Korea, Japan, Malaysia and USA) are active in the IEC process of harmonization RE standards internationally. The objective was to have at least 5 members in each committee and this was achieved by June 2006.

During this phase a progress report of the project was provided at the EGNRET meeting held in New Zealand in April 2006. The project manager, Mr Geoff Stapleton, was unable to attend but sent another representative, Mr Stephen Garrett.

Phase 4 involved establishing a technical secretariat to lead and support activities for each committee. Since it was identified early that to establish this secretariat in China as originally proposed would take more time than anticipated it was decided to select a person to act as leader of each committee, whose responsibility was to develop the review of existing standards and provide recommendations for harmonization.

The three committee leaders were:

- Ms Zhu Li (representing ISP and also coordinator for establishing ISP China and the technical secretariat)
- Mr Li Han, representing Qin Haiyan from China General Certification Center
- Mr Liang Ji, representing Underwriters Laboratory Inc

This allowed phases 5 and 6 to proceed while the project manager, Mr Geoff Stapleton, with the help of committee leader Ms Zhu Li, investigated the establishment of a person in China who could act as the secretariat. Advertising for the position was undertaken in June, interviews and an appointment were made in

July and the person, Mr Yunfeng Huang commenced his duties as an ISP representative and standards technical secretariat in August 2006.

During Phase 5 the project manager identified and purchased copies of all the relevant standards (member economies, IEC, IEEE and ISO) for each of the three priority areas. These were forwarded to the respective committee leaders who then developed a summary of the standards and a harmonization review. These were distributed by the project to the respective committees for comments.

During Phase 6 the reviews and the recommendations for harmonizing the respective standards were finalized by the technical secretariat, Mr Yunfeng Huang who is located in Beijing, China, in co-operation with the project manager. Due to the delay in providing the information from one of the committees, this was not completed until November 2006.

Phase 7 involved the distribution of the three harmonization reports throughout the APEC region and the development of the harmonization plan. The reports were sent to most of the standard organizations (those with identifiable e-mail addresses) within the member economies with a request for contact information on any committees that would oversee the introduction of similar standard within that member economy as well as requesting that the reports were forwarded to these committees. Unfortunately at the time of writing a response had only been made from Australian Standards.

In summary the harmonization action plan developed in this phase recommends:

- Contacting each of the standards association/organizations in each of the 21 member economies and identifying the person who is responsible (if any) for RE standards within that organization.
- Determining which member countries would be interested in developing harmonized standards in all or any of the three priority areas.
- Forming a committee to oversee the development of the harmonized standard.
- Developing the harmonized standard following the typical process for developing standards.

From experience within the IEC process, the harmonization of standards is a difficult and expensive process and takes many years. It requires many face to face meetings of people representing the standard organization from the various countries and commitment from each country to the harmonization process.

Though the objective of the project was to empower (or encourage) member economies to begin the process of harmonization of these three standards, the project teams believe this will be very difficult to achieve across all member economies. We would also anticipate reluctance from those member economies that have developed their own standards and/or are active in the IEC process.

So, even though the action plan developed in phase 7 would, assuming agreement by the majority of member economies standards organizations, lead to the development of a harmonized standard there is the possibility that due to the reason stated above, this might not be achieved across the whole of APEC. There could be agreement by some member economies to have an agreed standard and there might also be some agreement by some member economies to include parts of a harmonized standard in their existing national standard (see alternative plan)

Therefore alternative action plan has been developed. This involves helping the member economies which currently do not have a standard or standards that relate to the three priority areas in developing a national standard based on the harmonizing reports.

This project did identify that only; 7 member economies had existing solar water heating standards; 4 member economies had existing stand alone PV power system standards and only 6 member economies had grid-connected PV standards. The previous project identified that many of the member economies are installing grid connected PV systems, stand alone PV and hybrid systems and solar hot water systems. Therefore they do have a need for good quality standards in the three priority areas.

For these reasons the alternative harmonization action plan in summary involves:

- Notifying all standards organizations within member economies of this project and providing each with copies of the three reports that summarizes the existing standards and provides recommendations on harmonization.
- Encouraging those member economies with existing standards to use these reports when they next review their standard and adopt any of the recommendations if appropriate.
- Encouraging those member economies without existing standards to either develop their standards based on the recommendations or at least adopt an existing standard of one of the other member economies incorporating some or all of the recommendations.
- Using the established secretariat to support those member economies who want to develop a new national standard based on these reports.

2.0 Phase 1:Review Action Plan from APEC EWG/012002T Work

The project manager, Mr Geoff Stapleton, undertook a review of the previous project and action plan in September 2005.

The action plan identified the possibility of establishing a Standards Secretariat within an APEC economy that could oversee the harmonization of RE standards within the APEC economies and this had been proposed within the ISP project submission as being located in China.

The project manager investigated the legal requirements for establishing a secretariat within China and found that this would be expensive and will take some time to co-ordinate. To ensure that this current project would be completed on time the project manager invited three people to act as the chairs for the three committees that will be created.

The three people were:

- Ms Zhu Li (representing ISP and also co-ordinator for establishing ISP China and the technical secretariat)
- Mr Li Han, representing Qin Haiyan from China General Certification Center
- Mr Liang Ji, representing Underwriters Laboratory Inc

and all were selected from the team nominated in the ISP proposal.

The previous project had also:

- identified all the RE standards that were available at that time (2003) within the APEC economies
- Provided a needs analysis which highlighted the requirements for standards in each economy based on the RE applications and requirements within each economy

This section of the previous project was used to determine the three priority areas.

3.0 Phase 2: Determine top 3 priorities for review for harmonization

A meeting of the project manager and the three committee chairs took place in Shanghai on the 15th October, 2005

During the meeting Geoff Stapleton presented a review of the previous project. That project had looked at the need and availability of standards for both product and installation in the following areas:

- Solar water Heating
- PV Grid Connect
- Wind Generators-Grid Connect
- Stand Alone Power Systems
- Hydro Generators- Grid Connect
- Biofuels
- Geothermal
- Landfill Gas

From the review and discussions during the meeting it was determined that the three high priority areas were:

- Solar Water Heaters (manufacture and installation)
- Installation of PV Grid Connect Systems
- Installation of Stand Alone Power Systems

These three were selected for the reasons outlined in the next sections.

3.1 Solar Water Heaters

The report had identified that solar water heaters were being installed in 14 of the 21 economies and that there were solar water heater manufacturers in 13 of the 21 economies. Information had not been provided on the other 7 but it was expected that they were either being installed or there was potential for their installation.

Therefore since every house or commercial property in nearly every economy has the potential for solar water heating to be installed and the fact that 13 economies were identified as manufacturers then harmonizing standards for the manufacture and installation would be beneficial to all APEC economies.

3.2 Installation of Grid Connect PV Systems

The report had identified that 8 economies were currently installing PV grid connect systems and all economies were potential markets. Also 4 economies at that time had incentives and it is now known that 2 additional economies have introduced incentives.

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The grid connect system does comprise two major components- PV modules and inverters. In general most countries around the world are adopting the IEC standard for solar modules, so it was not necessary to develop an APEC only standards. The IEC is developing inverter standards and through the discussions it was determined that it would be difficult to harmonize inverter standards due to different safety requirements in different economies e.g. USA has UL while other economies do or do not recognize those standards.

Therefore, it was determined that a harmonized installation standard would be beneficial for those economies that had not introduced grid connected systems but have the potential to. It was also determined to attempt to develop a base standard that would be applicable to all economies as a starting point.

3.3 Installation of Stand Alone PV Systems

The report had identified that:

- 17 economies were currently installing PV stand alone powers systems
- no data had been received on 1 economy but it was reasonable to expect that they would be using stand alone systems
- 2 did not have a big need
- 1 was active in supporting stand alone systems in developing countries.

At that time 8 economies had incentives for the installation of systems.

For the same reasons as determined for grid connected systems it was decided not to include harmonization of product standards in this current project.

It was decided that a harmonized installation standard would be beneficial for the APEC economies.

3.4 Other Technologies and Applications

During the meeting geothermal and biofuels (biomass etc) were discussed but harmonization was not possible since there were no standards currently available in these areas.

Though large wind systems are being installed in many countries these were being installed satisfactorily and generally their interconnection to the grid was similar to any other large generating system so hence not a high priority for harmonizing any relevant standards. This also applies to mini-hydro systems.

Small wind was considered but it did not have the same market potential as those that were selected.

3.5 Selection of Committee Chairs

During the meeting the following chairs were selected:

- Mr Qin Haiyan- Chair of Solar Water Heater Committee
- Ms Zhu Li- Chair of Stand Alone PV Systems Committee
- Mr Jian Li- Chair of Grid Connect PV committee.

4.0 Phase 3: Identify experts and launch 3 expert technical committees

Once the three priority areas had been identified the project team, led by the project manager, invited people from various economies to join the committees. The project team did have concerns that many people who were active as “voluntary” standards committee members within their own economies would not be keen to be involved in more committees. Therefore the aim was to find at least five people for each committee.

The team manager and project team used their extensive network to identify the committee members. The committee members were either approached directly or contacts within economies were asked to nominate potential members. Standard letters had been developed to:

- Invite people to nominate potential committee members.
- Invite people to be members of a particular committee.
- Thank people when they had accepted their nomination.

Invitation letters went to people in the following economies:

- Australia
- Brunei Darussalam.
- Canada
- China
- Indonesia
- Japan
- Korea
- Malaysia
- New Zealand
- Philippines
- Singapore
- Thailand
- USA
- Vietnam

By the end of June 2006, 12 different people from 8 different countries had agreed to be members of the committees. The list of committee members and contact details are provided in Annex 1 of this report.

5.0 Phase 4- Creating a Technical Secretariat

The objective of Phase 4 was "to create a technical secretariat to lead and support activities for each committee".

As described in section 2 (Phase 1) of this report the legalities in hiring a person in China to act as technical secretariat for this project, as originally proposed, took a number of months to investigate. Committee leaders were selected to perform the role of the secretariat to ensure that the project was not delayed.

Once finalized, a company was hired to help with advertising the position and conducting the initial interview. A short list was provided and Mr Stapleton and Ms Zhu Li conducted interviews by phone and a person was selected. Mr Stapleton traveled to Beijing in July 2006 and conducted a face to face interview before appointing Mr. Yunfeng Huang to the position.

Mr Yunfeng Huang commenced in the position in late August 2006 and Mr Stapleton traveled to Beijing to conduct training on the APEC project. Mr Huang assisted Mr Stapleton with the project from that time.

Mr Huang will continue to represent ISP on a fulltime basis and therefore be in a position to act as the RE standards technical secretariat for APEC even after this project is completed.

6.0 Phase 5: Review of Existing Standards

The project manager purchased copies of all the relevant standards for each of the three priority areas. These are listed in Annex 2. During the initial project more standards were identified with respect to PV modules and other system equipment but many of these related to product only, not installation which was the focus of the priority areas.

The standards obtained were supplied to the technical committee chairpersons, who undertook a review and comparison of the initial standards. The comparison formed the basis of the development of the harmonization reports which were distributed to the committees for review and comments. The project manager acted as the coordinator for the distribution, follow-up and amalgamation of the comments for the respective reports.

7.0 Phase 6: Documentation of Harmonization Reports

Once the three reports had been completed by the committees, the technical secretariat under the guidance of the project manager edited the final reports for the three areas such that they were in a similar format. These are included as annexes 4, 5 and 6 to this report.

Unfortunately the grid-connect committee did not complete their review until November 2006 while the other committees had completed their work by early October 2006.

This resulted in this phase being behind schedule and not being completed until November 2006.

8.0 Phase 7: Activities to raise awareness of project and development of Action Plan

The harmonization reports that were developed during phase 6 were reformatted into stand alone reports (these versions are contained in the annexes).

The previous project produced a list of all standard organizations within APEC member economies. This was reviewed to ensure all contact details were still correct and updated where required.

Each of these organizations with e-mails on their websites was sent a copy of each of the three reports with a covering e-mail requesting:

1. Contact information for any internal committee involved with the development of renewable energy standards.
2. That these reports be forwarded to these committees (if they exist).

Those organizations without e-mails were contacted by fax requesting e-mail addresses.

Initially the reports were sent to 14 organizations where faxes were sent to 7 organizations requesting their e-mail addresses.

The project manager and the technical secretariat commit to respond to any questions or comments that are sent by any of these organizations even after this project has been completed.

The project team is currently developing a one page flyer on the project and the three harmonization reports. These will be printed in January 2007. Promotion of the project and the reports will be undertaken by ISP and the project managers company (Global Sustainable Energy Solutions Pty Ltd) at appropriate conferences and workshops attended by the two organizations over the next 12 months.

Mr Yunfeng Huang will continue to represent ISP in China and therefore the technical secretariat position will continue to exist and be in a position to support any harmonization of APEC RE standards.

9.0 Action Plans

9.1 Harmonization Action Plan

To effectively harmonize the standards for the three priority areas standards throughout the APEC region will require a fulltime standards secretariat liaising with the relevant standard organizations within each of the member economies. Development of the harmonized standard will require the following actions to be undertaken. All the actions will be managed by the standards secretariat.

a. Contacting the Existing Standards Organizations

Each of the standard organizations from each of the member economies has been identified and contact details are included in Annex 6 of this report. The Standards Secretariat would contact each of these organizations with the objective of identifying the person (or persons) who would be responsible for managing renewable energy standards within that organization. In some of these organizations this person (or persons) might not currently exist and it might require discussions by phone with the organization trying to identify whether that organization is interested in the development of RE standards. If so, who would they nominate to be responsible for that area? Obviously in some member economies the need for RE standards might not be a high priority. The outcome of this action is to develop a contact list of the actual person (or persons) within each member economy organization that is responsible for the development and management of RE standards. If there is a member economy who cannot provide a contact person but does have an interest then a mechanism shall be developed on how that member economy stays involved with the process.

b. Surveying the Organizations for interest in Harmonization of standards in the Three Priority areas.

A survey form will be developed and sent to the relevant contact person inquiring the level of interest for harmonizing the standards in either one or all of the three priority areas. It is hoped that some member economies that do not currently have people working in the RE area will still have a need within that member economy for a standard and would like to adopt any harmonized standard that is developed. The outcome of this action is to identify those member economies which are interested in developing a harmonized standard.

c. Understanding the System Structure of Standards Creation and Maintenance in each of the member economies.

Although almost all of the member economies have designated agencies under the governments for standards making and maintaining, the systems and structures are different, particularly for RE standards. The first step is to investigate and understand the differences in each of the member economies. The approach includes the study of the countries' reports, searching the relevant websites and interviewing the relevant experts in different countries.

d. Formation of Harmonization Committees for the three priority areas.

Those member economies that have expressed an interest in harmonizing the standards will be requested to nominate a maximum of two people to be on the harmonization committee. Three committees will be formed, one for the three priority areas. The people should come from the standards organization within that member economy and/or be a recognized national technical expert from the specific priority area.

e. Development of Outline of Harmonized Standard.

The standards secretariat should develop an outline of a harmonized standards (for each of the three priority areas) based on the harmonization reports developed during this project. The outline will include as a minimum the headings/titles of each of the sections of the proposed harmonized standard.

f. Distribution of Harmonization Reports and Standards.

The members of the committees shall be sent a copy of the: harmonization report; a copy of each of the available standards and a copy of the outline of the harmonized standard. They shall be asked to review the documents over a 2-3 month period.

g. Meeting of the Committees

After 3 months, a meeting (1 -2 days) of the three committees shall be arranged. These meetings could be held concurrently or separately and the exact location could be determined by the secretariat. During this meeting the committee shall finalize the outline of the harmonized standards.

h. Development of Harmonized Standard.

The harmonized standard shall then be developed by standards secretariat in liaison with the individual committees. This process will follow the standard process for developing a standard that is followed in most member economies. This process involves:

i. Development of preliminary draft standard by standards secretariat
ii. Distribution (electronically) of preliminary draft standard to committee for comments
iii. Compilation of comments by secretariat and meeting of committee to discuss comments.
iv. Development of next draft- this process could continue for a while until there is the development of the committee draft. Often this draft will be finalized at a meeting.
v. The committee draft is then distributed widely for public comment. This would be the responsibility of the standards organization within each active member economy to distribute within that economy and therefore collect comments. The distribution is typically to those members of the relevant standards committees within that member economy. The comments are then returned to the secretariat.
vi. The secretariat compiles a report on all the comments. A meetings is then held by the committees to discuss each of the comments. A final draft of the standard is developed by the secretariat based on the discussions with respect to the comments.
vii. The final draft is then distributed to each of the members of the committee to vote on the acceptance of the standard for the region. .

i. Publishing and Maintaining Standard

The harmonized standard is then published and a mechanism is established by the secretariat to review and maintain the standard on a regular basis, for example every 5 years or when a need arises.

9.2 Alternative Action Plan

The procedures for developing a harmonized standard as detailed in section 9.1 above is based on a typical process followed by standard organizations in developing a national standard within a member economy. From experience within the IEC process, the harmonization of standards across regions follows a similar process and it is a difficult and expensive process. Due to the sometimes varying specific requirements of different individual countries within the IEC, the process can take many years and at times have almost stalled. Similar problems could occur when trying to harmonize the standards across the APEC region.

Though the objective of the project was to empower (or encourage) member economies to begin the process of harmonization these three standards, it is expected that the action plan as detailed in section 9.1 could be very difficult to achieve across all member economies. There is a possibility that there could be reluctance from those member economies that have developed their own standards and/or are active in the IEC process to become involved in this harmonization process.

This project did identify that only; 7 member economies had existing solar water heating standards; 5 member economies had existing stand alone PV power system standards and only 6 member economies had grid-connected PV standards.

Australia and New Zealand either have common standards or are in the process of having common standards for each of the three priority areas while Mexico uses the USA standards for stand alone power systems.

Australia/ New Zealand, China and USA have standards in all three of the priority areas. In addition Canada, Japan and Chinese Taipei have water heating standards. Malaysia and Singapore also have grid connection standards.

In the study undertaken in the first phase of this project and from market developments over recent years, all member economies potentially will have a market for solar water heaters and grid –connected PV systems , while 18 of the member economies have an active market for stand alone power systems. Considering that the majority of member economies currently do not have national standards in these three areas some member economies might want to develop a standard for their needs.

If the harmonization process as detailed in section 9.1 is unable to be followed due to difficulties then an alternative process could be implemented where the information produced in this project could be used:

- To help individual (or groups of) members to develop their own standard based on the recommendation of the harmonization reports and/or
- By member economies when reviewing their existing standards..

The alternative action plan will be managed by the standards secretariat and include the following actions:

a. Contacting the Existing Standards Organizations

Each of the standard organizations from each of the member economies has been identified and contact details are included in Annex 3 of this report. The Standards Secretariat would contact each of these organizations with the objective of identifying the person (or persons) who would be responsible for managing renewable energy standards within that organization. In some of these organizations this person (or persons) might not currently exist and it might require discussions by phone with the organization trying to identify whether the organization is interested in the development of RE standards. If so, who would they nominate to be responsible for that area? Obviously in some member economies the need for RE standards might not be a high priority. The outcome of this action is to develop a contact list of the actual person (or persons) within each member economy organization that is responsible for the development and management of RE standards.

b. Distributing the Harmonization Reports .

The three harmonization reports will be sent to the relevant person in each of the standards organizations within the interested member economies.

c. Economies with Existing Standards

Those member economies with existing standards will be encouraged to use these reports when they next review their standard and adopt any of the recommendations if appropriate.

d. Economies without Existing Standards .

Those member economies without existing standards but want to develop a standard will be encouraged to either develop their standard based on the recommendations or at least adopt an existing standard of one of the other member economies incorporating some or all of the recommendations in the relevant reports

Annex 1: List of Technical Committee Members

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Annex 2: List of Existing Standards Obtained During Project

Solar Water Heaters

Australia/ New Zealand:

AS/NZS 2712:2002 :Solar and heat pump water heaters-Design and construction

Canada:

CAN/CSA-379.1-88 :Solar Domestic Hot Water System

China:

GB/T 19141-2003 :Specification of domestic solar water heating system

Japan:

JIS A 4111: 1997 :Solar water heater for dwellings.

Chinese Taipei:

CNS 12555, Solar Water Heater for Dwellings

United States:

E 1056-85 :Standard Practice for Installation and Service of Solar Domestic Water Heating Systems for One- and Two-Family Dwellings

Stand Alone Power Systems (Off-grid systems)

Australia/New Zealand

AS4509.1-1999 : Stand-alone power systems Part 1. Safety requirements

AS4509.2-2002 : Stand-alone power systems Part 2. System Design Guideline

AS4509.3-1999 : Stand-alone power systems Part 3. Installation and Maintenance

AS4086.2 -1997 : Secondary batteries for use with stand-alone power systems

China

GB/T 19115.1-2003 : Off-Grid type wind –solar photovoltaic-hybrid generate Electricity System of Household Use----Part 1: Technology condition

GB/T 19115.2-2003 : Off-Grid type wind –solar photovoltaic-hybrid generate Electricity System of Household Use----Part 2: Test methods

Mexico

National Electrical Code (NEC) 2005 Article 690

United States

National Electrical Code (NEC) 2005 Article 690

Grid-Connected PV Systems

Australia/New Zealand

AS 4777.1-2005 : Grid connection of energy systems via inverters Part 1: Installation requirement

AS 4777.2-2005 : Grid connection of energy systems via inverters Part 2: Inverter requirements.

AS 4777.3-2005 : Grid connection of energy systems via inverters Part 3: Grid protection requirements

China

GB/T 19939-2005 : Technical requirements for grid connection of PV system (in Chinese)

Malaysia

MS 1837-2005 : Installation of Grid-Connected Photovoltaic (PV) System

Singapore

Transmission Code – August 2002 Appendix F :Specific operating and technical requirements for generation, transmission and consumer installations. Published by Energy Market Authority of Singapore>

United States of America

UL 1741-2005 : Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

International

IEC 61727-2004 :Photovoltaic (PV) systems – Characteristics of the utility interface

IEEE 1547-2003 :Interconnecting Distributed Resources with Electric Power Systems (Note: IEEE standards are sometimes considered as USA standards, but at least in PV area, IEEE 1547 is a de facto international standard)

IEEE 1547.1-2005 :Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

Annex 3: Contact List of Standards Organizations in Member Economies

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Annex 4: Report of Solar Hot Water System Standards

Report is provided on following pages. The original was formatted as a separate document- so that it can be used as a stand alone document.

Table of Contents

1. Introduction

The purpose of this report is, through summarization of the provisions, and analysis of the different and common elements of the technical requirements and test methods/ procedure of the standards above, to provide recommendations or suggestions for an unified regional APEC standard for solar water heating system.

2. Standards Reviewed

Six national solar water heating system:
Australian/ New Zealand: AS/NZS 2712:2002 :Solar and heat pump water heaters-Design and construction..
Canada: CAN/CSA-379.1-88 :Solar Domestic Hot Water System.
China: GB/T 19141-2003 ;Specification of domestic solar water heating system
Japan: JIS A 4111: 1997 Solar water heater for dwellings
Chinese Taipei: CNS 12555, Solar Water Heater for Dwellings
USA: E 1056-85 :Standard Practice for Installation and Service of Solar Domestic Water Heating Systems for One- and Two-Family Dwellings

3. Summary of Solar Water System Standards

Table 1 summarizes all the technical requirements for solar water heating system in the six national standards. The table reflects the unified requirements for solar water heating system, in terms of scope, classification, general requirements, components, and type test, which are also the basic and necessary requirements. In addition, as the American national standard ASTM E 1056-85 is just for the installation and service, which is out of scope of the unified requirements, it is not as the major reference to consider about.

Table 1: Summary of Standards Comparison

Unified requirement \ Nations		AS/ NZS	Canada	China	Japan	Chinese Taipei
Scope*						
Classification*		Character 8	Character 1,2,4,5	Character 1-7	Character 9	Character 9
General requirements*						
Thermal performance	Collecting heat performance	●	●	●	●	●
	Heat insulating performance	●	●	●	●	●
Hot water supply performance			●		●	●
Water quality		●	●	●	●	
Pressure resistance	exchanger	●	●			
	system	●	●	●	●	●
Electrical safety		●	●	●	●	
Stagnation		●	●	●	●	

Backflow preventer			●	●		
Impact resistance		●	●	●	●	●
Freezing resistance		●	●	●	●	●
Outer heat impact				●		
Structure strength	Collector	●	●	●	●	●
	Storage tank				●	●
	Fittings	●			●	●
	Water heater body				●	
Overtemperature protection		●	●	●	●	
Inner heat impact				●		
Protection against ingress of water		●		●		
Components*						
Storage tank	Design	●		●		
	Insulating material	●		●		●
						●
Collector		●	●	●	●	●
Evacuated/vacuum tube				●		
Water pipes	Design	●	●	●	●	●
	Material	●	●	●		●
Pumps	Design	●				
	Compatibility					
Controller	Design	●	●	●		
	Control sensors		●	●		
Heat exchangers unit	Fluid	●	●	●		
	Heat exchanger	●	●	●		
Type Test						
Thermal performance	Collecting heat performance	●	●	●	●	●
	Heat insulating performance	●	●	●	●	●
Hot water supply performance			●		●	●
Water quality				●		
Pressure test	exchanger	●	●			
	system	●	●	●	●	●
Stagnation test		●	●	●	●	
Backflow preventer			●	●		
Impact resistance						●
Freezing resistance		●	●	●	●	●
Outer heat impact				●		
No load system performance test		●				
Structure strength test	Collector	●	●	●	●	
	Storage tank				●	●
	Fittings	●			●	●

Summary of Solar Hot Water System Standards

	Water body				●	●
Overtemperature protection	Fail-safe		●			
	Routine scalding	●	●			
Inner heat impact				●		
Protection against ingress of water		●		●		

Note:
mark "●" represents whether national standard specifies the corresponding requirements,
mark "*" represents there has a analysis in the following sections.

The following sections give the analysis of requirements and type test outlined in four different national standards with the purpose of providing the different and common element in them, and provide advice for the unified requirement.

3.1 Scope

The four national standards specify the requirements for:

AS/NZS:
It specifies requirements for the design and construction of solar water heater system with a storage capacity ≤ 700L

Canada:
It is concerned with the performance, durability, and safety of solar water heating system designed for use in small buildings.

China:
It covers the solar water heating system with a volumetric storage capacity up to and including 600L

Japan:
It specifies the solar water heaters to be mainly used for hot water supply for detached dwelling.

Summary
Through the provisions above, we can see that only Chinese and AS/NZS standards specify the requirement for storage capacity, and Chinese one is smaller than AS/NZS. As the storage capacity would affect the performance, the unified scope should specify the actual size- sale 600L.

3.2 Classifications

All the classifications specified in the four national standards is listed in the form below.

Table 2 Classification methods

Characteristic	Type		
	A	B	C
1	Solar only system	Solar preheat system	Solar plus supplemental systems
2	Direct circulation system	Indirect circulation system	
3	Open-outlet storage bank system	Vented storage tank system	Closed storage tank system
4	Overflow system	Drainback system	Draindown system
5	Thermosiphon system	Forced circulation system	
6	Circulation system	Direct flow system	
7	Remote storage system	Close-coupled collector storage system	Integral collector storage system
8	Solar water heater	Solar-boosted heat pump water heater	Air source heat pump water heater
9	Natural circulating system	Reserving system	Vacuum hot water storage system

Definition:

Character 1:

Solar Only System. A solar only system is a system designed to provide solar-heated domestic water without an auxiliary energy source.

Solar Preheat System. A solar preheat system is a system designed to provide solar-heated domestic water directly to another hot water heater.

Solar Plus Supplemental Systems. A solar plus supplemental system is a system designed to provide domestic hot water, using both solar and an auxiliary energy source in an integrated way.

Character 2:

Direct Circulation System. A direct circulation system is a system that circulates the potable water through the collector.

Indirect Circulation System. An indirect circulation system is a system that provides separation between the collector liquid and the potable water.

Character 3:

Open-outlet storage bank system. A system in which one pipe provides water and another pipe used for over flow.

Vented storage tank system. A system in which provision is made for a vent permanently open to the atmosphere.

Closed storage tank system. A system in which no provision is made for a vent permanently open to the atmosphere.

Character 4:

Overflow system. A system that its collector is filled with transfer liquid.

Drainback System. A drainback system is a system in which the liquid in the solar collectors is allowed to drain back into an indoor storage tank within the system under prescribed circumstances.

Draindown System. A draindown system is a system in which the liquid in the solar collectors is drained from the system under prescribed circumstances.

Character 5:

Thermosiphon System. A thermosiphon system is a system that utilizes only the change in density of the liquid due to differences in temperatures to cause transfer of heat between the collectors and storage.

Forced Circulation System. A forced circulation system is a system in which the heat transfer fluid is circulated by means of a pump.

Character 6:

Circulation system. A system in which the heat transfer liquid circulates between collector and storage tank/ heat exchanger unit

Direct flow system. A system in which heated water flowed directly from feed point through collector and to storage tank.

Character 7:

Integral collector storage solar water heater. A system in which the collector integral with storage bank.

Close-coupled collector storage solar water heater. A system in which the collector connected or close to the storage tank.

Remote storage solar water heater. A system in which the collector depart from storage tank.

Character 8:

Solar water heater. A system normally consisting of a collector and a storage tank, pipes, controllers, etc.

Solar-boosted heat pump water heater. A system consisting of a heat pump with an evaporator

exposed to solar radiation and a condenser delivering heat to a hot water storage container.

Air source heat pump water heater. a system consisting of a heat pump with an air source evaporator and a condenser delivering heat to a hot water storage container.

3.3 *General Requirements*

3.3.1 Thermal Performance

----Thermal collecting performance

	China	Japan	AS/NZS	Canada	Chinese Taipei
Test condition (Out door)	Solar radiation ≥ 17MJ/M^2 Feed water temperature equal to 20^{o}C Average ambient temperature range from 15^{o}C to 30^{o}C Average wind speed ≤ 4m/s	Solar radiation ≥ 167500KJ/M^2 Average ambient temperature ≤ 15^{o}C The difference between feed water and ambient shall be within ±5^{o}C Average wind speed shall be ordinary	Compliance with AS/NZS 3350.2.21	Compliance with ANSI/ASHRAE Standard 95	Average wind speed ≤ 4m/s
Test method	Similar, both using Mixing method (China has another method named draining method)				
Requirements	Close-coupled collector storage system and Integral collector storage system ≥7.5MJ/m^2 Remote storage system and Indirect circulation system ≥7.0MJ/m^2	≥8374Kj/m^2			≥7.0MJ/m^2

-----Heat insulating performance

	China	Japan	AS/NZS	Canada	
Test condition (Out door)	Initial feed water temperature 50 ^{o}C	Initial feed water temperature 35 ^{o}C ±2 ^{o}C	Compliance with AS/NZS 3350.2.21	Compliance with ANSI/ASHRAE Standard 95	Initial feed water temperature 35 ^{o}C ±2 ^{o}C
Test method	Not the same. Test time and formula are neither the same.				
Requirements	Close-coupled collector storage system and Remote storage system ≤22W/(m^3·K) Integral collector storage system ≤ 90 W/(m^3·K)	Vacuum hot water storage system≤80W/K·m^3 Natural circulating system≤5.81W/K			

Thermal performance consists of two important part, respectively solar collecting performance and heat insulation performance.
The table above indicates the requirements of four national standards for thermal performance. Although it only compares the specifications of Chinese and Japanese standards, but we can see that on the basis of same testing method, there are significant differences in terms of test condition, and test result demanding, because of different types of products, weather conditions, etc. Therefore, to harmonize different requirements, the expansion discussing should be implemented, and the ISO 9806-2 should be used for reference.

3.3.2 Hot Water Supply Performance

The requirement and type test in Japanese and Canadian national standards specify below:
Canada:
The purpose of the requirement is to the performance of auxiliary heating units, so the requirements only applies to the system with supplement heating devices, and the test requests the average temperature of any withdrawal should be not less than 50^{o}C.
Japan:
The purpose of the requirement is to evaluate the design of a system. And the test requests mean hot water supply quantity of the vented/ closed storage system should be not less than 0.01m^3 per min, and

Summary
Through comparison between the two standards above, we can see that the purpose, and requirements and test in Japan and Canada are quite different from each other. However, the two different requirements are really necessary for users. Therefore, a means of combining theses two methods together could apply to evaluate a solar only system /solar plus supplemental system of hot water supply/ recover performance.

3.3.3 Water Quality

Water quality is key point to the users' healthy, so there are detailed requirements for this. They specify the material in contact with water, such as lining of tanks, heat exchangers, water pipes, etc, should not pollute the water.
For ensure the requirement above, the water quality test in Chinese standard is imported, which would be an effective measure for ensuring users' healthy and safety.
China:
The solar water heating system filled with fee water should be placed for 2 days under the radiation ≥ 17MJ/M^2, after test, water would not be harmful for users.

3.3.4 Pressure Resistance

The purpose of the requirement is to ensure system the capacity of withstanding the pressure occurred during ordinary operation. The press test is required in each national standard. In addition, in Canada and AS/NZS, it is also required for the heat exchanger.
Although the purposes are the same, but the test among these standards are different.
AS/NZS
Compliance with AS/NZS 3350 or AS 4552(AG102)
Reference with the heat exchanger, add 1.5 times the maximum pressure or twice the marked setting of the relief valve or device for related systems for a period of 2 min

Canada
Add 1.5 times of design pressure for a period of 15 min
Reference with the heat exchanger, add 2000kPa pressure or twice the specified wording pressure or a minimum of 667kPa for related systems for 30min.
China
For closed storage tank system, select the larger one from 1.5 times of the pressure of the marked pressure and 1.25 times of rated pressure according JB 4732,
For vented storage tank system, pressure shall be equal to the rated pressure ＋ 0.05MPa
Japan
For closed storage tank system, add 290kp for a period of 2min; and add 740kp lasting 1min
For vented storage tank system, two times rated pressure, lasts 5 min; or, two times air pressure, lasts 1 min

Summary
Through the comparison, we can see that the conditions of the pressure test in these standards are different from each other, in case of different material used in storage tank and heat exchanger. Relatively speaking, the conditions used in Chinese standard may be more available for the system products prevailing in market, and the heat exchanger pressure test should be further discussed between AS/NZS and Canada.

3.3.5 Electrical Safety

	AS/NZS	***Canada***	***China***
Compliance with related standards	AS/NZS3350.2.21	CSAC191	GB4706.1、GB4706.12、GB8877

Now, auxiliary electrical equipments are widely used in solar water heating system. Therefore, each national standard put high prior on its safety. Through the table above, we can see that in the three national standards related electric safety standards are imported. So for unifying the regional standard, the further discussed should be implemented among these three nations, and related ISO/IEC standards should be considered.

3.3.6 Stagnation Test

This test is required in each national standard, although the purposes are the same, the test methods and procedures are different.
AS/NZS：
The test requests to use the thermal performance curve to estimate the maximum stagnation temperature.
Canada:
There are two ways, first is similar to AS/NZS, and the other way is to measuring the steady-state absorber plate temperature when the collector is operating at zero efficiency for conditions of 30°C ambient temperature and irradiance greater than 1000 W/m2.

China：
The test is a kind of aging resistance test. It requests that putting the system in the specified conditions, and after the test, check the appearance.
Japan:
It is a little stricter than Chinese. It requests after stagnation, a pressure test should be carried out later.

Summary:
We can see that AS/NZS and Canada look the same, and China and Japan are similar. The methods are all available. Therefore, the unified standard may import the two selectable methods. One is stagnation temperature estimation test (reference to AS/NZS), and ageing resistance test (reference to Japanese standard)

3.3.7 Backflow Preventer

Summarize the requirements of backflow preventer in the Chinese and Canada standards, it should specify:
For natural circulation system, the tank should on the top of collector.
For the forced circulation system, to prevent the increase of heat loss elicited by backflow, the preventer should be equipped.

3.3.8 Impact Resistance

Impact resistance is a very important test. It is required in four national standards, but the methods are a little different.
AS/NZS:
For a glazed collector, it should be impacted from a steel ball of 25.4mm nominal diameter;
For an unglazed collector, the height should be 2.9m
Canada:
The cover should be subjected to impact by.12 kg steel ball from a height of 3m,five separate impacts shall be conducted, four of these to occur at points located 150mm from each of the four corners and the fifth in the center of the cover plate.
China:
For flat plate collector, it should be impacted by a steel ball of (150g±10g) from 0.4m to 2.0m.
For evacuated tube collector, it should be impacted by a steel ball of 30mm in diameter from 0.45m
Japan:
The cover should be impacted by steel ball of 19.84mm in diameter (approximately 32g in mass) from a height of 50cm.

Summary
To harmonize a regional standard, it should apply for usual products in the market. Comparing these standards, we should make provisions for flat plate collector and evacuated tube collector that are leading products in the market.
For the glazed plat collector, we should use the test conditions from AS/NZS standards;
For the unglazed plat collector, we should use the test conditions from China;
For the evacuated tube collector, we should use the test conditions from China.

3.3.9 Freezing Resistance

This requirement is specified in each standard, but the test is not the same:

AS/ NZS:

There are two levels provided. First, a system should be able to withstand the effects of the temperature that warmer than -5 ^{o}C . And the second, a system should be able to withstand all frost conditions (from -15 ^{o}C to -17 ^{o}C) in Australia.

Canada:

The system should be protected from damage of freezing conditions which is defined by

(a) Stagnant or slowly moving water exposed to a temperature below 5 ^{o}C or

(b) Water in thermal contact with a nonfreezing liquid at less than 0 ^{o}C circulated through the system.

China:

First, a system with an initial feed water temperature of 45 ^{o}C should be resistance of 8h under condition (-20 ^{o}C ±2 ^{o}C),keep it for 2h.Then, filled with the water whose temperature is 10 ^{o}C, and last 8h under the condition of (-20 ^{o}C ±2 ^{o}C), then keep it for 2h.

Japan:

Generally, a system with an initial feed water temperature of 20 ^{o}C should be resistance of 15h under condition at (-15±2 ^{o}C) ambient temperature and pressure test.

Summary

Because of the difference of climate each country locates in, we can see that test requirements are different. So the unified test could apply to the different requirements of users, and test conditions could consist of several parts, such as ≥ -5 ^{o}C , -5 ^{o}C ~-10 ^{o}C, -10 ^{o}C ~-20 ^{o}C, additionally, at the end the test, add the pressure test like Japan and AS/NZS.

3.3.10 Outer Heat Impact

Because under the operation, a system usually suffers the rainstorm in a clear weather, which leads a sever impact to the system. So this requirement is imported, and this test is subject to Chinese standard to evaluate the capacity of the system to resist outer heat impact.

China

Its test requests that a system should be kept for 1 h under the condition of the radiation ≥ 800 W/m^2, and then sprayed with jets of water for 15 min. After the test, check its appearance.

3.3.11 Structure Strength.

It includes strength of collectors, storage tank, fittings, and water heater body.

AS/ NZS:

There are requirements for the strength of collector, and fittings on shell and collector. As the requirements, a collector should withstand the strength when it is applied vertically both upward and downward at any one of its corners with the other three corners rigidly fastened in a horizontal plane. And the fittings shall withstand without apparent distortion a torque.

China:

There only provides the requirement for rigidity of collector part.

Japan:

There are all-round requirements and tests for the rigidity of heat collecting part, tanks, water, fittings, and water heater body.

Summary

We can see that Japanese standard has all the requirements for the components, and its test methods are not incompatible with others. So the unified requirement should adopt the Japanese one, or mainly use it for reference.

3.3.12 Over Temperature Protection

This is a safety measurement mentioned in some national standards, in AS/NZS and Canadian standards, they provide test methods.

AS/ NZS:

It requests that the closed storage water heater should be fitted with temperature protection and press relief devices/ valves as required by AS/NZS 3350. the thermal discharge rating of the device/valve shall be not less than the total output power of the collector at 99 ^{o}C water temperature, 1200W/M^{2} radiation and 40 ^{o}C ambient. For the closed storage water heater with a volume of heat transfer fluid in the absorber and headers greater than 5L per square meter of aperture shall be fitted with a combination pressure- and temperature-relief valve. For the closed storage water heater fitted with an over-temperature protective device shall comply with AS 1308.

And there is a no load performance test for verifying the system capacity of over temperature protection. It requests for outdoor test that a system filled with hot water should continue for a minimum of 4 days until the collector has been subjected to 2 consecutive days in which the total daily solar irradiation has exceeded 25MJ/(m^{2}day), the maximum ambient temperature has exceeded 20 ^{o}C each day and the minimum overnight temperature was higher than 10 ^{o}C

Canada:

Each solar water heating system should be provided with pressure and temperature relief devices. Such relief devices shall operate without the use of a auxiliary power, and it should ensure the temperature of the water in storage bank can not exceed 99 ^{o}C under any operation conditions.

And there are two tests, named respectively fail-safe over temperature test and routine over temperature/scalding test. As in the fail-safe test, a system filled with the water temperature $\geq$ 60 ^{o}C should stand for 4h under the expected stagnation temperature. In the routine over temperature/scalding test, the system filled with 63 ^{o}C water or more to stand 8h under the condition of a irradiance of 1000w/m^{2} and ambient temperature of 30 ^{o}C

China:

It request that closed storage system should be equipped with the over temperature protection devices to guarantee no damage occurring to the system during no hot water use and auxiliary heating units being cut off. In addition, fixing any valves is not permitted between components and protection devices.

Summary

We can see that the for closed storage system, in the national standards above, there are clear requirements and tests, especially Canadian and AS/NZS. The unified standard could use the fail-safe over temperature test from Canadian test and routine scalding test from AS/NZS, or for reference.

3.3.13 Inner Heat Iimpact

It is from Chinese standard. And the purpose of this requirement is to ensure there will be no damage to system when the sudden exchange of the hot and cold water occurs, which would develop sever inner heat impact to the collector.
This requirement is subject to Chinese national standard. It specified the detailed testing procedure for flat plate system other than evacuated tube system.

3.3.14 Protection Against Ingress of Water

Purpose of this test is to check the extent of resistance of the ingress of water.
AS/NZS:
It requests that there shall be no measurable increase in the mass of the collector (no greater than 0.05kg) in each of three consecutive tests within the limits of accuracy of the measuring equipment. And the test applies spraying the collector with jets of water from nozzles for a period of 10 min, and at last measure the change of the mass of the collector to determine the results.
China:
It requests there should be no water ingress into collector, storage, vent hole, and draining hole. And its test use the jets of water from the nozzles to spry the collector, but the time would last 1 hour.

Summary
Through the comparison, we can see that the test way of Canada is more available for components, such as tank and collector, and Chinese test way is more available for the entire system. Therefore, the unified requirements could use the Canadian requirements and test for the remote storage system and Integral collector storage system, and Chinese requirements for the close-coupled collector storage system.

3.4 *Component*

3.4.1 Storage Tank

As the part of the solar water heating system, the tank is specified in the four national standards.
AS/NZS:
it specifies the requirements for the shell, thermal insulation, casing, attached feed tank, drain hole, and protection against ingress of water.
For shell, it requests that single and composite shell shall comply with the requirements of related standards, and fixing of electric heating units should be in accordance with the requirements of AS 1056, and all non-ferrous metal surfaces in contact with the contents of the tank shall be either electrically insulated from container walls or shall be covered on the surface of the fitting, for a distance of at least on diameter down the fitting, to protect against anodic reaction. In addition, the draining hole should be equipped.
For insulation should: (a) the insulation material shall be such that it will not deteriorate in service or become depressed and leave uninsulated voids during transportation or installation, or cause corrosion of any part of the water heater with which it is in contact. (b) The insulation shall be placed and contained so that its efficiency is maintained, contact with wiring terminations or temperature controls in prevented and attack by vermin is deterred.
And for tank itself, its casing should meet the requirements of AS 1056.1.

Canada:
It requests the tank should be drainable.
China:
It requests there should be the draining hole or overflow hole (for vented storage system) in tank, and the thermal insulation should comply with related standards and the difference of storage volume between actual testing and the remark on the product label should be within 10%.
Japan:
It only request any other material used for the facture of the storage tank.

Summary
Comparing with other standards, AS/NZS has more detailed and all-round requirements for the safety, thermal insulation and material. Therefore, to unify one standard, it is should be considered more.

3.4.2 Collector

As the most important part of solar water heating system, it has a great affect on the system performance, and most countries specifies the related standards to evaluate this component, so upon this unified system standard, a unified collector standard should be developed, which would combine relevant standards refers in these four national standards.

3.4.3 Evacuated Tube

This product mainly is produced in China, and China has already edited the standard for evacuated standard, so this requirement should be subject to Chinese national GB/T 17049-2005 standard.

3.4.4 Water Pipes

The material and design of the pipes are highlighted by each national standard.
AS/NZS:
It request that water pipes should comply with AS/NZS 3500.4.2 , and a weather-resistant seal shall be used, and withstand outdoor conditions.
Canada:
It requests that the piping loop should be designed in accordance with recognized piping standard and plumbing codes. Additionally, the type and minimum thick of insulation shall be specified by the system manufactures for all piping that is required for the installation.
Japan:
it requests the detailed requirements of the material to be used for connecting pipes.
China:
it requests the design of water pipes and thickness and facture of heat insulation.

Summary
We can see that the design and material used for water pipes would be different in different place. In some countries, there are some related standards for these requirements. So the unified requirement should consider about it, either making another standard or just ordering the design or material should comply with local standards.

3.4.5 Pumps

It is mainly used for remote storage system.
Canada:
It requests the selection, sizing and location of the pump.
China:
It requests the its compatibility with water.

Summary
The requirements for pump are relatively less than other components. The unified requirements should be combine the requirements of China and Canada together.

3.4.6 Controller

It is widely used for the system, providing the increase of automatic capacity
AS/NZS:
it requests that the controls, including those incorporated in multiple function devices, should comply with AS 1308.
Canada:
In this standard, the pressure and temperature relief devices required should be considered as controllers. And all the controllers should maintain the solar water heating system within the temperature- and pressure-operating limits as required by design. Additionally, the control subsystem should be designed so that, in the event of a power failure or a failure of any of the components in the subsystem, the temperature or pressure, or both developed in the solar water heating system will not be damaging to any of the components of the system and the building or present a danger to the occupants.
China:
It request that the controllers should comply with GB/T 14536.1, and sensors installed in collector should withstand the temperature of stagnation, with the temperature precision of ±2 ^{o}C,and sensors installed in storage tank can withstand the temperature of 100 ^{o}C, with temperature precision of ±1 ^{o}C.

Summary
We can see that there are related electrical safety standards the controllers should be complied with in the AS/NZS and China standards, so the unified requirements should be furthered discussed with the these countries, and the requirements developed by Canada for the fail-safe and requirements for sensors installed in collector and storage tank should be taken into the unified standard.

3.4.7 Heat Exchangers Unit

This device is widely used in closed storage system, so some standards pay much attention to its performance.
AS/NZS:
There is an individual part for the requirement for the exchanger units; it includes the requirement of fluid and exchanger.
For fluid, it requests that fluid should not degrade into more toxic, or corrosive, components when exposed to minimum or maximum temperature and pressures for the manufacturer’s nominated design life of the system.
For the exchanger, it requests the design, material, strength of material, and over-pressure internal test.

Canada:

It requests that the fluids and exchangers should meet the requirement for healthy and safety, in terms of material, chemical compatibility.

For the fluids, it shall be nontoxic, and the flashpoint should not be lower than the highest of 50 ^{o}C above the design maximum operating temperature.

For the exchangers, especially the single-wall heat exchanger, the wall material that separates the potable wager from the heat transfer fluid should be a stainless steel with a minimum thickness of 1.4mm.

China:

It requests the fluid's chemical compatibility with water and the consideration of the cleaning or scaling.

Summary

Apparently, the requirements of AS/NZS and Canada are specified in detail, especially AS/NZS, it relatively covers the requirements of Canada. Therefore, to establish the unified standard, the AS/NZS should be used for reference.

4. Conclusion

In a word, according to the difference of environment, climate, and development of solar water heating system, harmonizing and establishing an APEC standard for solar water heating system mainly needs the followed further work:

First, because of the different requirements and test procedures for performance and safety in different countries, to form the unified requirements scientifically should be further discussed around a committee, using related ISO and EN standards for reference.

Secondly, some requirements of components or material in the four different national standards refers to their own related standards, which were not reviewed.. Thus, the further work should focus on this point, if necessary, another unified standards for components or material should be established, such as collector, water pipes.

Annex 5: Stand Alone Power Systems Standards Report

Report is provided on following pages. It has been formatted as a separate document- so that it can be used as a stand alone document.

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Table of Contents

1. Introduction

The report summaries Installation Standards of Stand-alone PV (wind hybrid) system in selected APEC economies, which include both developed and developing countries. It has been identified there are 17 APEC economies currently installing PV stand-alone systems. China, Australia and the United States have specifically issued the Installation of PV Stand-alone PV (wind hybrid) Standards, the harmonization recommendation and plan in the report are based on the review of the standards from the three countries.

2. Standards Reviewed

Stand-Alone PV (wind hybrid) system standards in Australia, China and United States.

- Australia
  - ❖ AS4509.1-1999 Stand-alone power systems Part 1. Safety requirements
  - ❖ AS4509.2-2002 Stand-alone power systems Part 2. System Design Guideline
  - ❖ AS4509.3-1999 Stand-alone power systems Part 3. Installation and Maintenance
  - ❖ AS 4086.2 -1997 Secondary batteries for use with stand-alone power systems
- China
  - ❖ GB/T 19115.1-2003 Off-Grid type wind –solar photovoltaic-hybrid generate Electricity System of Household Use----Part 1: Technology condition
  - ❖ GB/T 19115.2-2003 Off-Grid type wind –solar photovoltaic-hybrid generate Electricity System of Household Use----Part 2: Test methods
- United States
  - ❖ National Electrical Code (NEC) 2005 Article 690

3. Summary of Stand-alone Standards

Although different countries have different specifications in their standards, and in some cases in accordance with other national standards, in general, the installation of PV stand-alone standards comprises the following sections:

- Scope
- System Design and Technical Requirements
- Installation
- Testing and Commissioning
- System Maintenance
- Safety Requirements

The summary of the review of the Standards for the three countries is listed in table 1.

Table 1: Summary of Review of Stand-Alone Standards

			Australia				**China**		**USA**
	Standard		**AS 4509.1-1999**	**AS 4509.2-2002**	**AS 4509.3-1999**	**AS 4086.2-1997**	**GB/T 19115.1-2003**	**GB/T 19115.2-2003**	**National Electrical Code (NEC) 2005 Article 690**
	Form		paper/ pdf	paper/ pdf	Paper/ pdf	Paper/ pdf	doc final	doc final	paper/pdf
No									
1	**Scope**								
	General								
2	**System Design and Technical Requirements**	General		●					
		Resource		●			●		
		Electrical		●			●		●
		Mechanical and Civil Works		●			●		
		System Performance		●			●		
3	**Installation**	Installation and cable protection			●		●		●
		PV arrays			●		●		●
		Wind Turbine Generators			●		●		
		Battery Bank			●	●	●		
		Generating set			●		●		
		Equipment layout			●		●		
		Other Equipment			●				
4	**Testing and Commissioning**	Wiring			●		●		
		Polarity			●				
		Charging sources			●			●	

		System Functional Test			●		●	●	
5	**System Maintenance**	electric wiring			●				
		wind turbine			●				
		PV Array			●				
		generating set			●				
		battery bank			●	●			
		other items			●				
6	**General comments**	System documentat ion			●			●	
7	**Safety Requirement s**	Wiring and Circuit Protection	●						●
		Equipment	●						●
		Shutdown procedure	●						●

The following sections are the analysis of system design, installation, testing, maintenance and safety requirements outlined in four different national standards with the purpose of providing the different and common element in them, and provide advice for the unified requirement.

3.1 Scope

The national standards specify the requirements for scope as follows:

Australia:

Used for supply of extra-low and low voltage electric power, with energy storage at extra-low voltage

***China*:**

Applicable to PV Wind hybrid system of household-use <5 kW

USA:

Apply to solar photovoltaic electrical systems, including the array circuit, inverters, converters

Summary:

Different standards define the scope with different conditions. China focuses on the power, while Australia uses 'extra-low and low voltage' (defined as not exceeding 50 V a.c. or 120 V ripple-free d.c).US standard is not specific to standalone system, so its scope is out of our concern. The suggestion for harmonization is to combine both China and Australia.

3.2 System Design and Technical Requirements

3.2.1 General

Australia:

System design is guided by a number of criteria to consider lowest economic life cycle cost, lowest environmental impact and site constraints etc.

Summary:

Australia has given valuable guidance and it's good to base the harmonization upon it.

3.2.2 Resource

Australia:

Solar resource: using existing long term data, and adjustment to data should be made for both climate variations and shading. Wind resource: record is kept at Australian Bureau of Meteorology, 12 month on site measurement should be considered at least height of 12 meter. Adjustment should be made between measurement site and installation site.

China:

Solar resource: annual solar radiation >=5000 MJ/m2, wind resource: annual average wind speed >3.5 m/s. a system shall work reliably under the following environment conditions: outside temperature: -25°C--+45°C, room temperature: 0°C--+45°C, humidity: <=90%,altitute <=1000m.

Summary:

Both standards have the same concern but as we can see Australia has more specific and clear statements in this section.

The two countries focus different perspectives of resource data:

- China regulates the minimum resource condition to ensure the system minimum output. However, no requirements on data measurement and does not specify which existing climate data can be used for resource assessment.
- On the other hand, Australia focuses on the availability and measurement of the resource data and how to use the existing data.

It is recommended in the Chinese standards to include the session of the measurement and the valid use of existing climate data for resources assessment. In Australia standard, the minimum requirements of resource data, particularly wind speed, should be specified to ensure the minimum system output.

3.2.3 Electrical

Australia:

High efficiency lights, efficient refrigerator are recommended as well as power factor correction if necessary.

Detailed Demand assessment method is given, including the consideration of stand-by load and possible further household appliances. Based on the demand the selection of wind generator/PV arrays, etc are introduced.

Where the daily design load energy equals or exceeds 1kW/day, seasonal variation of daily energy demand is also required

China:

For wind generators: power capacity shall be calculated based on annual average wind speed, lowest monthly wind speed, period of annual non-effective wind speed and annual power load and average monthly off peak load. Rated wind speed shall be determined by average lowest monthly wind speed

For PV module: Wp shall be determined by daily average lowest power load and peak sunshine hours, as well as system loss factor. The minimum power capacity shall be 1.8 times of average lowest power load.

For controller: It shall have separate circuit for wind generator and PV.

$W_{windchargingmax}=2\ W_{ratedoutput}$, $W_{PVcharingmax}=1.5W_{ratedoutput}$

For inverter: its output power >1.5 PV output power.

For battery: lead acid battery, output voltage shall in accordance with output voltage of wind generator and same as PV output voltage, battery shall be fitter with dump load, of which output power >1.2 system output power capacity

USA：

Maximum voltage: in a DC PV source circuit, Maximum voltage shall be calculated as the sum of the rated open circuit, voltage of the series connected PV modules corrected for the lowest expected ambient temperature.

Summary:

Australia has more specific and detailed terms, For example, PV module orientation and tilt angle have been taken into consideration, and focuses on the method of demand assessment while China and the US regulate the method of measuring the system output. . So it's recommended to integrate the demand assessment into Chinese and the US standards.

3.2.4 Mechanical and Civil works

Australia:

All activities should aim to minimize environmental impact.

For PV Array: Sitting, unshading for at least for 4 hours before and after solar noon.

For Wind Turbine: the height of tower should be high enough to raise the turbine above turbulence caused by obstacles in the vicinity. tower design should comply with AS 1170.2, For Genset: It should allow for an adequate air flow, easily assessable, reduce noise, and attention on air discharge, discharge end of the exhaust pile should be fitted with weather protection, and include a muffler to reduce noise. Any fixed point should include flexible sections to withstand the vibration.

For Battery: Battery enclosure refer to AS 2676.1 and AS 2676.2, 4.7 noise control.

China:

The installation of wind turbine should be in accordance with JB/T 10395, *Installing regulations for off-grid wind turbine generator system*. In this standard, detailed guides on the civil works are given, including digging, piling, concreting, etc.

Summary:

China has detailed requirements for wind turbine installation,. Australia has complete requirements for all the main parts as well as the concern to environmental impact. Since the two countries have different standards on environmental impact, and Chinese stand-alone systems are mostly used in rural remote areas, whereas, Australia systems are mostly for domestic use, and the mechanical and civil works are different in countries due to the geography and economical difference, the harmonization can set only the necessary requirements for safety and operation rather than in detailed civil works requirements.

3.2.5 System Performance

Australia:

Performance specification should be based on the equations and other considerations outlined in the document

China:

A system shall work reliably under the following environment conditions: outside temperature: -25°C--+45°C, room temperature: 0°C--+45°C, humidity: <=90%,altitute <=1000m.

Summary:

China defines the environment conditions with which the system should work reliably. Australia makes sure that the system will meet the previous demand estimation and system design. Both of them can be put into the harmonization.

Summary for system design:

The system design requirements in China and Australia are different due to the different system function. For example, the PV stand-alone system in China is mainly used for electrification in rural remote areas, where normally have harsh environment and geographic condition, and it is expected to need minimum maintenance. However, in Australia and the US, the system is applicable to all general conditions. So in the harmonization, all these differences should be taken into consideration.

3.3 Installation

3.3.1 Installation and Cable Protection

Australia:

Installation shall be of adequate strength and should be protected against mechanical failure, under normal condition of use, wear and tear.

Cabling shall be protected in accordance with AS 3000.

China:

All components shall be connected through wiring, no socket allowed. The connection between system output and external circuit shall use wiring connection, or using socket for system output. Double direction socket shall not be used. Wiring should be protected with isolation, wiring shall use fixed bolt.

USA:

Permitted methods are listed for wiring systems, single-conductor cable, flexible cords and cables, small-conductor cables and etc. There are also specific requirements for component interconnections, connectors, access to boxes and ungrounded PV power systems.

Summary:

All these three standards have similar technical requirements although they have different descriptions.

3.3.2 PV arrays

Australia:

General: PV array comprising a number of modules should be connected with suitable blocking diodes in series with each series connected string, where nominal array voltages are greater than 24V.

Tilt and orientation: an array should be arranged to have a fixed orientation face within ±5º of true north, the tilt angle of a fixed array should take account of the seasonal variation of load, adjustable title should be marked to indicate either the tilt angle in degrees or the time of the year the array should be in each position. A tracking array should face within ±5º of true north. Installation: roof penetration should be sealed and waterproof, wiring should have UV and mechanical protection, PV array should be installed to minimize temperature rise, and mounted.

China:

PV array mounting should use anti erosion fixed frame, frame strength should be able to resist for 120km/h wind, loss of current and voltage shall less than 2%, shall fitted with lightening protection in frequent lightening happen area.

Unshading during sunshine hours, minimum distance between PV array and ground >1.2 m, for roof top system, minimum distance between PV array and roof material >10 cm, lightening protection for roof top system, fence protection in the human and animal passing area

USA:

The connections to a module or panel shall be arranged so that removal of a module or panel does not interrupt a grounded conductor to another PV source.

Summary:

China and Australia has similar terms in this section.

3.3.3 Wind Turbine Generators

Australia:

Tower site should be level and with sufficient area, footings should be installed by c competent person, tower installation shall be supervised by a licensed rigger with appropriate safety equipment. Installation should be comply with manufacture's instruction and all wiring have UV and mechanical protection, all moving part should be ensured no movement is possible during maintenance operation.

China:

Wind turbine generators shall fitted with lightening protection in frequent lightening happen area. Installation should be in accordance with JB/T 10395, *Installing regulations for off-grid wind turbine generator system*. JB/T 10395 asked certificated or specially trained people to perform the installation after carefully reading the manual. Detailed requirements of civil work were given as well as the procedure of tower installation. Installation in bad weather days(heavy rain, strong wind, or fog) are forbidden.

Summary:

Both China and Australia has detailed requirements on the installation of wind turbine generators while Australia has also mentioned requirements for the tower site.

3.3.4 Battery Bank

Australia:

In accordance with the requirement of AS 4086.2, battery termination should be crimped, bolted connection should use stainless steel, and tightened to the manufacture's specification and checked 30 days later and then annually. Exposed battery cabling should be mechanically protected. No metal to be worn during battery work.

There are specifications for the ventilation in size and location. In AS4509-There are specifications that no electrical or spark producing items can be located above the batteries.

In AS4509 there are specifications for restricting access to authorized personal and they should b in a dedicated enclosure.

China:

In accordance with operational instruction, with ventilation, prevent entry of children and hands, in residential area, shall use sealed battery, dump load shall have ventilation, no covering, no flammable goods close by.

Summary:

These two are similar. Australia and China has set safety requirements while Australia also emphasizes the periodic check. A combination of them will be fine in the harmonization.

3.3.5 Generating Set

Australia:

in accordance with the requirement of AS 3010.1. Generating set shall be mechanically restrained and flexible cable or cord should connect to the fixed wiring at a nearby junction box, and be protected from mechanical damage and wear, generating set should have ventilation, noise control, air inlet and exhaust conditioning

China:

Interconnection of all parts should be fixed and reliable, without use of electrical outlets and plugs.

Summary:

Most of the requirements for generating set have been stated in the previous part for PV, wind turbine.

3.3.6 Equipment layout

Australia:

To minimize cable losses, system component should be mounted as close as possible, only authorized person to access equipment, all electrical equipment should have ventilation

China:

Controller and inverter, dumpload should be put into one same box which has good ventilation and is not easy to be touched.

Connect converter and inverter first, then connect controller and battery, cover the PV module, then connect PV system to controller, shutdown the wind generator system, then connect to controller.

Summary:
Both China and Australia have similar requirements on ventilation, limited access, etc.

3.3.7 Other Equipment

Australia:
Lightening protection to all equipment, in accordance with AS1768, Battery chargers shall be permanently connected to the battery bank via battery fuse or circuit-breaker, charger output cabling shall be protected from over current, electronic regulators are used to protect battery overcharging, inverter cabling should be kept as short as possible and inverter is securely positioned. All metering and alarm equipment shall be labeled to identify its use and placed in a convenient, accessible and visible location.

China:
The installation of controller, inverter and dumpload should be in accordance with relative electric standards as well as manufacturer's manual.
The dumpload can't be covered by anything else and should keep away from inflammable and explosive goods.

Summary for installation:
All these three countries have their own national standards for system installation. From technical point of view, because the installation procedure and technical requirements have no big difference in different countries, this section should be relatively easy to harmonize. The Australia standards have more specific and clear statements in this section, hence, it is recommended to develop a regional standards based on the Australia standards.

3.4 Testing and Commissioning

3.4.1 Wiring

Australia:
All wiring shall be tested for continuity and short circuits.

3.4.2 Polarity

Australia:
Polarity shall be checked at the main fuses and then progress out to the ELV circuits furthest from the battery bank. A voltmeter shall be used to confirm voltage and polarity, while circuit protection and equipment are being connected.

3.4.3 Charging Sources

Australia:
Before connection, the following should be carried out: (a) The PV array checked for wiring and operation, (b) Wind generators checked for wiring and operation, (c) generating set output voltage and frequency checked, (d) PV regulators checked for correct operating voltages and currents, (e) battery chargers should be checked for correct operation and voltages. All measurements should be recorded as initial operating parameters.

China:
Maximum charging voltage should be tested(1.5 times of the normal voltage of PV array, 10 minutes) as well as maximum charging current.
PV charge circuit voltage drop, anti-reverse connection and dump-load test should also be performed.

Summary:
Although China and Australia has similar technical concern while Australia was more complete.

3.4.4 System Function Test

Australia:
The overall function of the complete system should be tested and the results documented. All input sources should provide charge to the battery bank and, where applicable, power should be available to any connected extra-low voltage appliances
China:
Need to test all metering in normal position before commissioning
The following items should be tested for 3 times and documented and keep the records: stability of output frequency, variation of output wave, protection test, battery overcharge and less charge protection and automatic recovery, shortcut circuit protection, overload protection, over load protection, empty load voltage protection and dump load function test. Detailed test procedure is given.

Summary for test and commissioning
All parts should have been tested by manufacturers and delivered with a quality certificate. So the test and commissioning of the stand alone system is to ensure that the whole system works well. Australia is more complete, but on the parts which they both have, China is more clear and specific. So the recommendation is to take the advantage of detailed Chinese standard and to use Australian to complement where required.

3.5 System Maintenance

3.5.1 Electric Wiring

Australia:
A periodic inspection should be performed
A correctly installed electrical wiring system normally needs infrequent maintenance, but periodic inspection of cabling security, electrical connections and mechanical protection should be performed.

3.5.2 Wind Turbine

Australia:
The maintenance on the wind turbine generators and associated equipment should be carried out in accordance with the manufacturers instructions.

3.5.3 PV Array

Australia:
Quarterly check out: clean PV modules surface, Adjust array tilt seasonally, array mounting security, mechanical cable protection.
Annually check out: electrical integrity, PV array charging voltage and current

3.5.4 Generating Set

Australia:

Maintenance of the engine and alternator, including routine maintenance requirements such as oil and filter changes and adjustments, tune-ups and overhauls, should be carried out in accordance with the manufacturer's instructions.

3.5.5 Battery Bank

Australia:

Before carrying out maintenance and inspection, the precautions should be taken: isolate the battery bank; use isolated tool, prevent short battery terminals, any hydrogen build-up has been thoroughly expelled. The battery enclosure should be fully cleared of hydrogen gas before entry
or performance of any maintenance.
Check least quarterly: battery connection, battery bank, battery electrolyte level, keep record.

3.5.6 Other Items

Australia:

Regular maintenance checks should be performed in accordance with manufacturer's instructions. If no recommendation is available, annual checks should be carried out on battery charger operation, regulator/controller operation, meter reading, inverter operation, operation of isolating devices.

Summary for maintenance:

System maintenance has quite different requirements in each country. For instance, in China, the systems are mostly used in remote rural areas, where systems are required to have minimum maintenance. Whereas, in Australia, systems are required to have at least quarterly check and maintenance. A further discussion on minimum system maintenance within the committee is required.

3.6 General Comments

3.6.1 System Documentation

Australia:

The following documentation should be provided: (I) system manual: list of equipment supplied, system performance estimated/guaranteed, operating instruction, shutdown and isolation procedure for emergency and maintenance, maintenance procedure and timetable, commissioning records and installation checklist, warranty information, original energy usage estimate, system connection diagram, equipment manufactures' documentation and handbooks, (II) battery record logbook, (III) generating set service logbook.

China:

Report should include following info: 1) test time, place 2) test condition 3) test objective 4) main tested parameter 5) test results and quality analysis 6) test conclusion 7) testing staff.

Summary:
China focuses on recording of the system test. Australia gives more wide and complete documentation list, including the instructions for future operation, maintenance, warranty, etc. The Australia one will be a good basis for future harmonization.

3.7 Safety Requirements

3.7.1 Wiring and Circuit Protection

Australia:
All Low voltage and Extra-low voltage wiring shall be installed and maintained by licensed person and in accordance with AS 3000, and comply with additional local requirements.
Wiring should be protected from short circuit and overload, lightning protection comply with AS 1768.
The system shall be adequately earthed, low voltage equipment earthing should be in accordance with AS 3000
USA:
Circuit over 150 volts to ground shall only be accessed by qualified person

3.7.2 Equipment

Australia:
Generating set: It shall be restrained from moving and prevented from starting when inspection, repair and maintenance. Put warning notice for automatic and remote manual starting.
Fuel storage: It should comply with AS 1940. It should keep away from possible high temperature, arcs. Specific requirements have been set according to the class of the fuel.
Towers and PV mounting structure: in accordance with AS 1170.2
Wind tower guy wiring: shall be mechanically protected from inadertent human or animal contact, with conduit to a height of 2 meters, material shall have a durable and high visibility.
Battery: safety and warning signs as well as good ventilation are required. Battery enclosure shall prevent entry by children.
Any equipment with moving parts and high temperature parts or emission shall be protected.
Multiple LV sources: comply with AS/NZS 3131, an unconnected socket shall be provided and marked, and warning notice shall be clearly visible. Either an isolation switch or a contactor shall be fitted
There should be safe isolation between ELV and LV circuits.
USA:
Over current protection: PV sources circuit, PV output circuit, inverter output circuit, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240

3.7.3 Shutdown Procedure

Australia:
Each installation shall have a 'shutdown procedure' sign, including: emergency de-energization procedure (including the locations of all isolation devices) and maintenance shutdown procedure.

USA:
Means shall be provided to disconnect all current-carrying conductors, equipments and the fuse which is energized from both directions. These means shall be access to other than qualified persons. And these disconnecting means shall not be installed in bathrooms. The disconnecting means for ungrounded conductors shall consist of a manually operable switch(es).

Summary for safety requirements:
The regional standards should have minimum safety requirements based on the existing items in Australia and the US standards. There is no safety requirement specifically for installation of PV (wind turbine) Stand-alone system in Chinese standards. However, all electrical engineering safety should be in accordance with national standards. It is recommended to develop a regional comprehensive safety requirement for installation and maintenance of PV (wind hybrid) Stand-alone systems.

4. Conclusion

The major differences of these national standards are the system design and maintenance; this is mainly due to the different system function. For instance, the PV stand-alone system in China is mainly used for electrification in rural remote areas, where normally have harsh environment and geographic condition, and require minimum maintenance, while in Australia and the US, the system is applicable to all general conditions. Most of the sections in these standards need to be in accordance with other national standards, such as electrical engineering and wiring etc, these standards vary in different countries in terms of quality, performance, safety and even training of the technical engineering.

The standard harmonization in APEC region for installation of PV stand-alone systems needs to focus on the following sections:

1. System installation for PV array and wind generator, and battery bank
2. System maintenance (including battery maintenance)
3. Safety requirements

Annex 6: Report on Grid-Connected PV Systems Standards

Report is provided on following pages. It has been formatted as a separate document-so that it can be used as a stand alone document.

Table of Contents

1 Introduction

The report summaries grid-connect PV system in selected APEC economies, which include both developed and developing countries. It has been identified that Australia, China, Malaysia, Singapore and the United States have specifically issued the grid-connect PV standards, the harmonization recommendations in the report are based on the review of the standards from the five countries, and international standards by IEC and IEEE.
Note: It is said that there is a guideline for grid-connected PV system in Japan. The guideline is published by the agreement between power utilities and manufacturer of inverter under the support of government. It is only in Japanese.

This report is mainly focused on the electrical quality and protection requirements. These requirements are generally fulfilled through inverters which are traded internationally, therefore, harmonization's are very important.

On the other hand, the review and harmonization recommendations are not given in this report for grid-connect PV system installations. The reason is that due to the local technical traditions, economic conditions, climates, etc. the installations are basically localized, and the harmonization's are not so critical at present time. If a member economy does require an installation standard then the Australian and Malaysian standards can be used as a reference source. These standards include the interconnection of the PV array to the inverter and the inverter to the grid. They detail the required protection devices , isolators, cable sizing , voltage drop and safety signage
.

2 Standards Reviewed

The grid-connect PV standards reviewed in the report including:

- Australia
    - ❖ AS 4777.1-2005 Grid connection of energy systems via inverters Part 1: Installation requirement
    - ❖ AS 4777.2-2005 Grid connection of energy systems via inverters Part 2: Inverter requirements
    - ❖ AS 4777.3-2005 Grid connection of energy systems via inverters Part 3: Grid protection requirements
- China
    - ❖ GB/T 19939-2005 Technical requirements for grid connection of PV system (in Chinese)
- Malaysia
    - ❖ MS 1837-2005 Installation of Grid-Connected Photovoltaic (PV) System
- Singapore
    - ❖ Transmission Code – August 2002 Appendix F Specific operating and technical requirements for generation, transmission and consumer installations. Published by Energy Market Authority of Singapore.
- United States of America

- UL 1741-2005 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- International
  - IEC 61727-2004 Photovoltaic (PV) systems – Characteristics of the utility interface
  - IEEE 1547-2003 Interconnecting Distributed Resources with Electric Power Systems (Note: IEEE standards are sometimes considered as USA standards, but at least in PV area, IEEE 1547 is a de facto international standard)
  - IEEE 1547.1-2005 Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

3 Summary of Grid-Connect PV System Standards

Although different countries have different specifications in their standards, and in some cases in accordance with other national standards, in general, the grid-connect technical specification and requirement standards comprise the following sections:

- Scope
- Voltage
- Frequency
- DC injection
- Harmonic voltage
- Harmonic current
- Power factor
- Anti-Islanding

Std / Unified requirement	Australia	China	Malaysia	Singapore	US	International	
						IEC	IEEE
Scope	•	•	•	•	•	•	•
Voltage	•	•		•	•	•	•
Frequency	•	•		•	•		•
DC injection	•	•		•	•	•	•
Harmonic voltage				•			•
Harmonic current	•	•			•	•	•
Power factor	•	•			•	•	
Anti-Islanding	•	•			•		•

The summary of the review of the standards is listed as following:

3.1 Scope

Australia

Up to 10KVA for single phase and 30KVA for three-phase. Similar principles are applicable to larger systems.

China

For low voltage grid connected systems.

Malaysia

For PV system Voc up to 1000V between positive and negative conductors or up to +/- 1000V with respect to earth.

Note: Based on an email communication with a Malaysia expert on 7/15/06, it is applicable to either +1000V or -1000V, but not both. That means it is not applicable to systems with total of 2000V from positive to negative, although the grounding is in the middle of the voltage range.

Singapore

There is no specification on the Transmission code Appendix F, since the code is applicable to all kind of generations.

United States of America

For all distributed resource technologies, with aggregate capacity of 10 MVA or less (adopted from IEEE 1547).

International

IEC: For systems rated at 10 kVA or less, such as may be utilized on individual residences single or three-phase.

IEEE: For all distributed resource technologies, with aggregate capacity of 10 MVA or less.

Summary:

For all distributed resource technologies, with aggregate capacity of 10 MVA or less.

3.2 Voltage

Australia

If out of following ranges, disconnect in 2 seconds.

- Vmin shall lie in the range 200-230 V for a single-phase system or 350-400 V for a three-phase system;
- Vmax shall lie in the range 230-270 V for a single-phase system or 400-470 V for a three-phase system;

The limits Vmax and Vmin may be either preset or programmable. The values Vmax and Vmin may be negotiated with the relevant electricity distributor.

China

For three-phase system, voltage fluctuation shall be less than +/- 7% of the grid, for single-phase system, voltage fluctuation shall be between +7% and -10% of the grid.

Singapore

The connection of the PV system shall not cause voltage fluctuation at the point of common coupling to exceed 3% of the nominal voltage.

United States of America

The same as International below.

International

IEEE:

Grid-connect PV systems do not normally regulate voltage. They inject current into the utility. Therefore, the voltage operating range for PV inverters is selected as a protection function that responds to abnormal utility conditions, not as a voltage regulation function.

The PV system shall parallel with the grid without causing a voltage fluctuation at the point of common coupling greater than ±5% of the prevailing voltage.

The voltage ranges and their clearing times are given in Table 1. Clearing time is the time between the start of the abnormal condition and the PV system ceasing to energize the grid. For system less than or equal to 30 kW in peak capacity, the voltage set points and clearing times shall be either fixed or field adjustable. For system greater than 30 kW, the voltage set points shall be field adjustable.

Table 1—Interconnection system response to abnormal voltages
(IEEE 1547-2003 Table 1)

Voltage range (% of base voltage) [1]	Clearing time (s) [2]
V< 50	0.16
50 < V< 88	2.00
110 < V < 120	1.00
V > 120	0.16

[1]Base voltages are the nominal grid system voltages.
[2]PV system size ≤ 30 kW, maximum clearing times; PV system size > 30kW, default clearing times.

The PV system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the grid steady-state voltage is restored to the ranges identified above.

IEC:

When the interface voltage deviates outside the conditions specified in Table 2, the photovoltaic system shall cease to energize the utility distribution system. This applies to any phase of a multiphase system.

All discussions regarding system voltage refer to the local nominal voltage.

The system shall sense abnormal voltage and respond. The following conditions should be met, with voltages in RMS and measured at the point of utility connection.

The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive nuisance tripping. The unit does not have to cease to energize if the voltage returns to the normal utility continuous operation condition within the specified trip time.

Table 2 – Response to abnormal voltages
(IEC61727-2004 Table 2)

Voltage (at point of utility connection)	Maximum trip time [1] (s)
V < 50% Vnominal	0.1
50% ≤ V < 85%	2.0
85% ≤ V _ 110%	Continuous operation
110% ≤ V < 135%	2.0
135% < V	0.05

[1] Trip time refers to the time between the abnormal condition occurring and the inverter ceasing to energize the utility line. The PV system control circuits shall actually remain connected to the utility to allow sensing of utility electrical conditions for use by the "reconnect" feature.

Summary:

Grid-connect PV systems do not normally regulate voltage. They inject current into the utility. Therefore, the voltage operating range for PV inverters is selected as a protection function that responds to abnormal utility conditions, not as a voltage regulation function.

The PV system shall parallel with the grid without causing a voltage fluctuation at the point of common coupling greater than ±5% of the prevailing voltage.

The voltage ranges and their clearing times are given in Table 1. Clearing time is the time between the start of the abnormal condition and the PV system ceasing to energize the grid. For system less than or equal to 30 kW in peak capacity, the voltage set points and clearing times shall be either fixed or field adjustable. For system greater than 30 kW, the voltage set points shall be field adjustable.

Table 1—Interconnection system response to abnormal voltages
(IEEE 1547-2003 Table 1)

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V< 50	0.16
50 < V< 88	2.00
110 < V < 120	1.00
V > 120	0.16

[1]Base voltages are the nominal grid system voltages.
[2]PV system size ≤ 30 kW, maximum clearing times; PV system size > 30kW, default clearing times.

The PV system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the grid steady-state voltage is restored to the ranges identified above.

3.3 Frequency

Australia

If out of following ranges, disconnect in 2 seconds.

- f_{min} shall lie in the range 45-50 Hz; and
- f_{max} shall lie in the range 50-55 Hz.

The limits f_{max} and f_{min} may be either preset or programmable. The values f_{max} and f_{min} may be negotiated with the relevant electricity distributor.

China

50Hz +/- 0.5Hz.

Singapore

The unit shall be capable of sustained operation within the system frequency range which is normally controlled within the limits of 49.5Hz – 50.5Hz and, in some exceptional circumstances, it could rise to 52Hz or fall to 47Hz.

The generating unit shall operate within the frequencies range of 52Hz to 47Hz in accordance to the following:

52Hz – 47.5Hz: continuous operation is required

47.5Hz – 47Hz: generating unit is required to remain in operation for at least 20 seconds each time frequency falls below 47.5Hz.

United States of America

The same as International below.

International

IEEE:

The frequency ranges and their clearing times are given in Table 3. Clearing time is the time between the start of the abnormal condition and the PV system ceasing to energize the grid. For system less than or equal to 30 kW in peak capacity, the frequency set points and clearing times shall be either fixed or field adjustable. For system greater than 30 kW, the frequency set points shall be field adjustable.

Table 3—Interconnection system response to abnormal frequencies
(IEEE 1547-2003 Table 2)

PV system size (kW)	Frequency range (Hz)	Clearing time (s) [1]
< 30	> 60.5	0.16
	< 59.3	0.16
	> 60.5	0.16
> 30	< {59.8 – 57.0} (adjustable set point)	Adjustable 0.16 to 300
	< 57.0	0.16

[1] PV system size ≤ 30 kW, maximum clearing times; PV system size > 30 kW, default clearing times.

The PV system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the grid steady-state frequency is restored to the ranges identified above.

Summary:

The frequency ranges and their clearing times are given in Table 3. Clearing time is the time between the start of the abnormal condition and the PV system ceasing to energize the grid. For system less than or equal to 30 kW in peak capacity, the frequency set points and clearing times shall be either fixed or field adjustable. For system greater than 30 kW, the frequency set points shall be field adjustable.

Table 3—Interconnection system response to abnormal frequencies
(IEEE 1547-2003 Table 2)

PV system size (kW)	Frequency range (Hz)	Clearing time (s) [1]
□< 30	> 60.5	0.16
	< 59.3	0.16
	> 60.5	0.16
> 30	< {59.8 – 57.0} (adjustable set point)	Adjustable 0.16 to 300
	< 57.0	0.16

[1] PV system size ≤ 30 kW, maximum clearing times; PV system size > 30 kW, default clearing times.

The PV system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the grid steady-state frequency is restored to the ranges identified above.

3.4 DC Injection

Australia

It shall not exceed 0.5% of its rated per-phase output current or 5 mA, whichever is the greater.

China

The PV system shall not inject DC current greater than 1 % of the rated current into the grid.

Singapore

The PV system shall not inject any dc current into the grid.

United States of America

The PV system shall not inject DC current greater than 0.5% of the full rated output current into the grid.

International

IEC: The PV system shall not inject DC current greater than 1 % of the rated current into the grid.

IEEE: The PV system shall not inject DC current greater than 0.5% of the full rated output current into the grid.

Summary:

The PV system shall not inject DC current greater than 0.5% of the full rated output current into the grid.

3.5 Harmonic Voltage

Singapore

Table 4 The limits of total, individual odd and even harmonic voltages

Voltage range	Total harmonic voltage distortion (%)	Individual odd harmonic (%)	Individual even harmonic (%)
230V and 400V	< 5.0	< 4.0	< 2.0
6.6kV and 22kV	< 4.0	< 3.0	< 2.0
66kV	< 3.0	< 2.0	< 1.0
230kV	< 1.5	< 1.0	< 0.5
400kV	< 1.5	< 1.0	< 0.5

International

IEEE:

The voltage harmonics while powering a resistive load at 100% of the machine kVA rating shall not exceed the levels in Table 5. Voltage harmonics shall be measured line to line for 3-phase/3 wire systems, and line to neutral for 3-phase/4-wire systems.

Table 5—Maximum harmonic voltage distortion in percent of rated voltage (IEEE 1547-2003 Table 6)

Individual harmonic order	**$h < 11$**	**$11 \le h < 17$**	**$17 \le h < 23$**	**$23 \le h < 35$**	**$35 \le h$**	**Total harmonic distortion**
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

Summary:
The voltage harmonics while powering a resistive load at 100% of the machine kVA rating shall not exceed the levels in Table 5. Voltage harmonics shall be measured line to line for 3-phase/3 wire systems, and line to neutral for 3-phase/4-wire systems.

Table 5—Maximum harmonic voltage distortion in percent of rated voltage (IEEE 1547-2003 Table 6)

Individual harmonic order	**h < 11**	**11 ≤ h < 17**	**17 ≤ h < 23**	**23 ≤ h < 35**	**35 ≤ h**	**Total harmonic distortion**
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

3.6 Harmonic Current

Australia
The same as IEC below.
China
The same as IEC below.
United States of America
The same as IEC below.

International
IEEE:
When the PV system is serving balanced linear loads, harmonic current injection into the grid shall not exceed the limits stated below in Table 6. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the grid without the PV system connected.

Table 6—Maximum harmonic current distortion in percent of current (I) [1] (IEEE 1547-2003 Table 3)

Individual harmonic order h (odd harmonics) [2]	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	Total demand distortion (TDD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[1] I = the greater of the local grid maximum load current integrated demand (15 or 30 minutes) without the PV system, or the PV system rated current capacity (transformed to the point of common coupling when a transformer exists between the PV system and the point of common coupling).
[2] Even harmonics are limited to 25% of the odd harmonic limits above.

IEC:
Low levels of current and voltage harmonics are desirable; the higher harmonic levels increase the potential for adverse effects on connected equipment. Acceptable levels of harmonic voltage and current depend upon distribution system characteristics, type of service, connected loads/apparatus, and established utility practice.

The PV system output should have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system.
Total harmonic current distortion shall be less than 5 % at rated inverter output. Each individual harmonic shall be limited to the percentages listed in Table 7. Even harmonics in these ranges shall be less than 25 % of the lower odd harmonic limits listed.

Table 7 – Current distortion limits
(IEC 61727-2003 Table 1)

Odd harmonics	**Distortion limit (%)**
3 – 9	<4.0
11 – 15	<2.0
17 – 21	<1.5
23 – 33	<0.6
Even harmonics	**Distortion limit (%)**
2 – 8	<1.0
10 – 32	<0.5

Note: Testing harmonics is very problematic, since voltage distortion may lead to enhanced current distortion. The harmonic current injection should be exclusive of any harmonic currents due to harmonic voltage distortion present in the utility grid without the PV system connected. Type tested inverters meeting the above requirements should be deemed to comply without further testing.

Summary;
When the PV system is serving balanced linear loads, harmonic current injection into the grid shall not exceed the limits stated below in Table 6. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the grid without the PV system connected.

Table 6—Maximum harmonic current distortion in percent of current (I) [1]
(IEEE 1547-2003 Table 3)

Individual harmonic order h (odd harmonics) [2]	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	Total demand distortion (TDD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[1] I = the greater of the local grid maximum load current integrated demand (15 or 30 minutes) without the PV system, or the PV system rated current capacity (transformed to the point of common coupling when a transformer exists between the PV system and the point of common coupling).
[2] Even harmonics are limited to 25% of the odd harmonic limits above.

3.7 Power Factor

Australia

PV system shall be in the range from 0.8 leading to 0.95 lagging for all output from 20% to 100% of rated output.

China

PV system shall be in 0.9 leading or lagging when output >50% of rated output.

United States of America

The output of a utility-interactive inverter shall have a power factor of 0.85 or higher when the unit is connected to the rated dc input and to a simulated utility source and operated at 100 percent of the rated output. The unit shall also be tested at 25 and 50 percent of rated output.

International

IEC:

The PV system shall have a lagging power factor greater than 0.9 when the output is greater than 50 % of the rated output power.

Summary:

The PV system shall have a lagging power factor greater than 0.9 when the output is greater than 50 % of the rated output power.

3.8 Anti-Islanding

Australia

Any situation where the electrical supply from an electricity distribution network is disrupted and one or more inverters maintains any form of electrical supply, be it stable or not, to any section of that electricity distribution network. Disconnect within 2 sec of disruption to the power supply from grid.

China

The same as IEEE below.

United States of America

The same as IEEE below.

International

IEEE: For an unintentional island in which the PV system energizes a portion of the grid, the PV system shall detect the island and cease to energize the grid within two seconds of the formation of an island.

Note: island is a condition in which a portion of the grid is energized solely by one or more PV systems while that portion of the grid is electrically separated from the rest of the grid.

Summary:

For an unintentional island in which the PV system energizes a portion of the grid, the PV system shall detect the island and cease to energize the grid within two seconds of the formation of an island.

4 Conclusion

It is recommended that the standard harmonization in APEC region for grid-connection PV systems to follow the IEEE 1547, and only add or change some national deviations if necessary. The review and harmonization recommendations are not given in this report for grid-connect PV system installations. If a member economy does require an installation standard then the Australian and Malaysian standards can be used as a reference source

APEC Publication Number 206-RE-01.8