2014 ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Peer Reviewed
2014 Solar Research Conference

PV System Reliability – Preliminary Findings from the PV Module and System Fault Reporting Website

Anis Zaman[1], David Parlevliet[1], Martina Calais[1], Sinisa Djordjevic[1], Sandy Pulsford[2], Anna Bruce[3], Rob Passey[4],

[1]School of Engineering and Information Technology, Murdoch University, Murdoch WA 6150, Australia
[2]Clean Energy Council, Melbourne Vic 3000, Australia
[3]School of Photovoltaic and Renewable Energy Engineering, The University of New South Wales, Sydney NSW 2052, Australia
[4]Centre for Energy and Environmental Markets, The University of New South Wales, Sydney NSW 2052, Australia

E-mail: D.Parlevliet@murdoch.edu.au

Abstract

Solar Photovoltaic (PV) system installations are enjoying a continued and remarkable growth in Australia. Currently there are over a million PV systems installed in the country with an installed capacity of over 3.5GW, the majority of which are small grid-connected rooftop systems of less than 10kW capacity. Australian conditions can be very harsh, contributing to early equipment failure rates, while installation of small systems can be suboptimal, and often without monitoring. Documentation of faults with PV products and installations in Australia is limited and there is little publically available information in regards to the types of problems that occur, where and why they occur, how frequently and if they are an ongoing issue.

The reliability of PV systems is a strong determinant of cost effectiveness, and critical to continued investor confidence. A ‘PV Module and System Fault Reporting Portal’ (PVFRP) has been developed to increase the understanding of the PV industry and other stakeholders about the types of problems that are found with different system components in the Australian environment. The PVFRP contains a survey to collect data from owners, operators, installers and inspectors of PV system who have detected a fault/problem with whole or part of a system. Analysis and dissemination of the Portal data will help to improve future PV system design, component selection, product development and product approvals for Australian conditions. The survey is available at: www.surveymonkey.com/s/pvwebportal.

This paper presents the initial findings of the survey after five months of operation. The number of responses received thus far is not large enough to reach to any substantive conclusions, however, they are in agreement with the research outputs achieved elsewhere. This information will help the industry address the challenges that PV systems, components and related service delivery are facing in Australia. The information presented here will be updated as more data become available and will be published on a regular basis.

1. Introduction

Australia’s total installed PV capacity has increased significantly over the last decade, in particular since 2009, with more than 350,000 systems installed in 2011. Up to August 2014, 1,286,330 PV systems had been installed, with a capacity of over 3.5GW (Clean Energy Regulator, 2014). The drop in installed capacity in 2013 was due to the changes in the feed-in tariffs by State and Territory Governments, and changes in the solar rebate by the Federal Government (Watt et al., 2013).

There has been a significant cost reduction of PV modules, which has resulted from the shifting of module and inverter production to China. This led to a significant uptake of PV systems in Australia during 2010-2012, which indicates that the Australian PV market is mostly price driven, rather than quality focused. This could be partly because the incentives for PV systems are provided upfront and no long-term performance incentives are available.

There has been a significant variation in the number of PV systems installed in different Australian States and Territories. The majority of the systems have been installed in Queensland (399,240), followed by New South Wales (273,448) and Victoria (225,869).

2. Performance and reliability

The introduction of generous incentives between 2008 and 2010 saw large numbers of PV modules from low cost manufacturers begin to enter the Australian PV market. Despite the standards and approval processes that were put in place to safeguard the quality of products and services, some customers reported irregularities in the visual appearance of their solar modules after a relatively short period of time in the field (Djordjevic et al., 2014). In addition, an increased number of problems were found to be associated with early failure of system components, and others with the system installation and balance of system components, such as the use of inadequate/underrated components that are not compliant with PV standards and installation guidelines (Calais et al., 2011). These trends are major concerns, as they represent safety and fire hazards. In addition, they are likely to lead to lost energy production and increased expenditure on maintenance and repair services to bring failed PV systems back to working condition. Thus reliability of PV systems impacts the levelised cost of electricity from PV systems and increases uncertainty in returns on investment. A good understanding of PV system reliability is critical to continued investor confidence, access to financing for PV and a sustainable market.

The 'PV Module and System Fault Reporting Portal' (PVFRP) described here will provide the PV industry and stakeholders with information about the types of problems that are found with different system components when they are exposed to Australian environments, which will highlight technical aspects of PV systems that need improvement, and allow suppliers, manufacturers and service providers to improve future PV system design, component selection, product development and product approvals for Australian conditions. Analysis of the data and project outputs could also inform development of standards and guidelines, and enable comparisons to be made of performance, reliability and economics in different climate zones. It is anticipated that the wider community will benefit from these outcomes in future by being able to source more reliable, higher quality, safer components and systems.

3. PV Fault Reporting Portal

The PVFRP is open to owners, operators, installers and PV inspectors and can be found at: www.surveymonkey.com/s/pvwebportal. It has been developed as part of the project 'Data Collation & Analysis for Development of a Climate-based PV Module Rating Scheme', supported by the Australian Renewable Energy Agency (ARENA). The PVFRP is coordinated by Murdoch University in collaboration with the Australian PV Institute (APVI), Clean Energy Council (CEC), University of New South Wales (UNSW), National Renewable Energy Laboratory (NREL) and Centre for Alternative Technology (CAT). There are very few similar fault reporting portals available in the public domain. One major international system is managed by NREL[1], which aims to collect information on the reliability and performance issues associated with PV system components. NREL's Photovoltaic Module

[1] Available at http://www.nrel.gov/pv/performance_reliability/

Field Failure Database allows people to submit information about faults they have observed in PV modules. NREL's database records information on physical damage, visual changes, delamination, electrical damage and degradation in performance. By way of contrast, the PVFRP is designed to target PV users in Australia and collect localised information.

The PVFRP is intended to collect information about which part of a PV system has failed, and details about the failed equipment, mainly based on visual inspection; which the literature suggests is a powerful tool to identify causes of failures of PV modules, or to identify problems that could cause failures in the future. While many causes of reduced performance are not visible and need to be detected with more sophisticated tools, visual inspection is quite effective for identifying hot spots, delamination, encapsulant yellowing, back sheet blistering, junction box failure, etc. (Djordjevic et al., 2014; Kontges et al., 2014). The PVFRP also encourages module manufacturers to provide data collected from warranty returns.

PVFRP respondents can remain anonymous, however they are encouraged to provide at least one mode of communication in case a clarification is required. Further inspections may also be necessary to determine whether the defects identified by visual inspection are reducing system output. The PVFRP consists of a structured online questionnaire using SurveyMonkey. The PVFRP contains the following six sections:

a) *Introduction*: The introduction section provides the general background to the project, description of target survey respondents, how data will be managed/used, privacy policy and reference to Ethics approval. It also provides "safety instructions" for the respondents, which will need to be understood and adhered to in filling out the questionnaire. The contact details of key researchers are also available at the end of this section, so that respondents can get in touch with the research team, if necessary.

b) *Solar Module*: This section allows the respondents to report on faults and issues related to solar modules. A list of faults that may be experienced with solar modules is provided. The participant chooses one fault type at a time and answers a number of related questions. The participant then has the option to return to the fault list (if there are more faults to be reported) or go to the next section.

c) *Inverter*: As with the Solar Module section, the participant is required to choose one fault type at a time and then answer related questions before they can provide data for another fault type.

d) *Other Equipment*: Unlike the Solar Module and Inverter sections, this section allows respondents to report on multiple fault types related to other equipment, and so they do not need to go back to the fault list.

e) *Installation*: As with the Other Equipment section, this section allows respondents to report on multiple fault types related to installation.

f) *General Comments*: This section allows the participant to report faults and issues that were not possible to report in the previous sections. An open text box has been provided to help describe the nature of any faults as well as to provide general comments.

4. Results/findings

4.1. General findings

The PVFRP has generated a high level of interest among people associated with the PV industry. During the first five months, a total of 29 respondents have reported issues regarding PV system components and installation in Australia. Figure 1 shows the type of respondents reported using this portal and Figure 2 presents the geographical distribution of the respondents.

The majority (17 out of 25), of faults and issues have been reported by the owner/operator. There have been also reports from 3 installers and 2 from PV industry associations. While four reports have been recorded from Victoria, most of the other States recorded between two to three reports. However, at this point of time, there have not been any reports from Tasmania, the Northern Territory and the Australian Capital Territory.

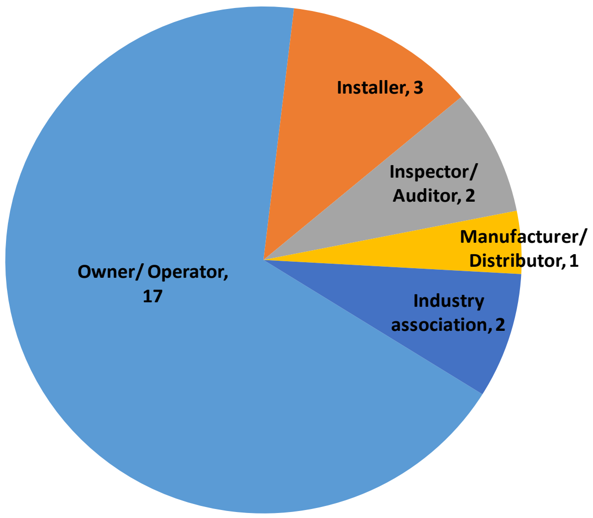

Figure 1: Respondents by type

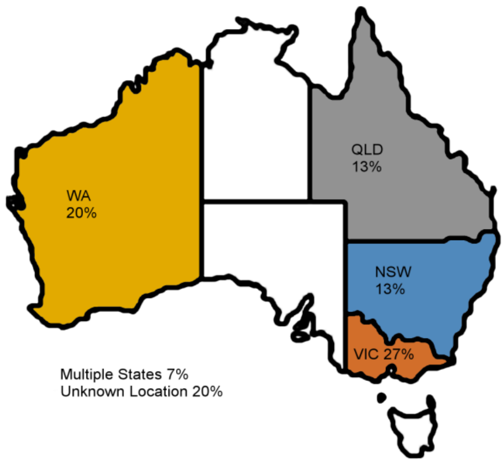

Figure 2: Geographical distribution of respondents

About half the respondents (11) did not provide their contact details for potential follow-up. This could be because they preferred to remain anonymous or they simply did not want to be contacted again. The sizes of systems reported lie within the range 1kW to 20kW, with most of the reports lodged for systems of 0kW to 5kW. Most of the systems (19) reported are grid-connected and do not have batteries. This is to be expected as the bulk of the small scale systems in Australia are of this category (Watt et al., 2013).

The respondents reported on different issues related to PV Modules, Inverters, Other equipment (e.g. framing, isolators, battery, etc.) and installation. Figure 3 shows the number of issues reported for each of these categories.

4.2. PV module

The PV module section of the questionnaire is designed to collect information on a range of issues. Ten different pre-set module problem types are suggested to the respondents. These problems were chosen after a literature review, as they have all been commonly identified in other similar research undertaken elsewhere (Calais et al., 2011; Djordjevic et al., 2014; NREL, 2014). All of the problem types were also identified by respondents to the PVFRP.

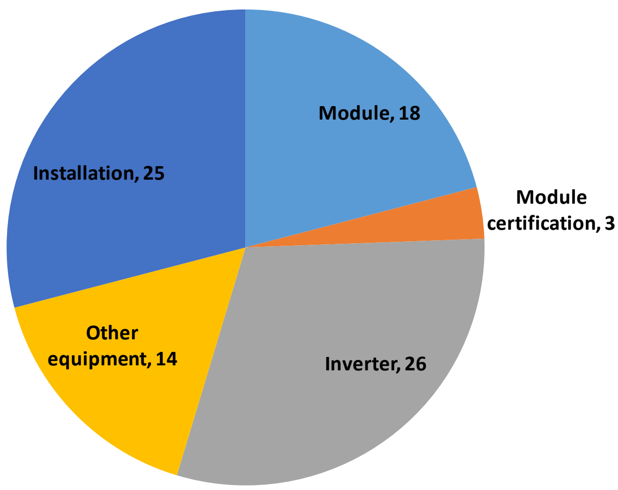

Figure 3: Faults reported by components and services

Table 1 shows that the ten different types of module faults were reported by 18 respondents. The fault types vary widely and no particular type of fault stands out. Glass breakage and problems with the backsheet (e.g. bubbling, delamination, hole, etc.) were found to be the top two issues. Glass breakage can be caused by a number of factors, including improper installation of the modules, for example by over-tightening the mount screws. This can lead to electrical safety issues because the insulation of the modules can no longer be guaranteed, and can also lead to the development of hot spots (localised overheating of one or more cells in the module which can lead to further damage (Kontges et al., 2014).

Table 1: Module fault types reported by the respondents

Module fault type	Number of reports
Glass Breakage	3
Backsheet (e.g. bubbling, delamination, hole)	3
Junction box (e.g. loose contact, burnt diode, etc.)	2
Cell Interconnect (e.g. burn marks)	2
Water ingress and internal corrosion	2
Variation in power output between panels under same conditions	2
Encapsulant Discolouration	1
Cell discolouration	1
Module cable or connector	1
Framing	1

The other problems found with the PV module included: loosening of the junction box and its contact points, water ingress, and variation of output between panels of the same brand and model under the same conditions. The IEA Photovoltaic Power Systems (PVPS) Task 13 Review of Failures of Photovoltaic Module presents typical problems found with PV modules during a visual inspection in accordance with IEC PV standards (Kontges et al., 2014). The problems reported are very similar to those found in this survey, such as bubbling, delamination, loose contact of junction box and burnt diodes. However, the report does not mention water ingress, which appears to be a concern in Australian conditions. An investigation of faults on solar modules in Western Australia also identified similar types of faults (Djordjevic et al., 2014). These included cell discolouration, snail trails, delamination, hot spots, glass breakage and junction box corrosion.

NREL has also prioritised different problems based on their frequency of occurrence, and the need for the industry to address them. The high to medium priority faults associated with modules are (Bosco, 2010):

- Corrosion leading to loss of earthing
- Quick connector reliability
- Improver installation leading to loss of earthing
- Delamination
- Glass breakage
- Bypass diode failure
- Junction box failure
- Weak diodes, hot spots, etc.
- Moisture ingress, and
- Busbar failure – mechanical (adhesion) and electrical

In general, the PV module faults reported thus far through the PVFRP are similar to those identified by other researchers.

4.3. Inverter

The inverter is the second major component of a PV system and a significant cause of system failure. A study at Tucson Electric Power showed that 69% of unscheduled maintenance costs for PV systems were attributed to inverters (Kurtz et al., 2009).

Most of the critical faults reported to the PVFRP were related to the inverter (Figure 4). About half of the reported inverters (10 inverters) suffered complete failures while eight inverters had partial failures. Respondents also commented on customer support issues in relation to inverter failures: Getting a faulty inverter fixed can take a very long time, with one of the inverters taking 48 months to be replaced. Inverter safety and performance issues have been also highlighted by the respondents. Three of the inverter faults did not cause a failure but affected system performance. These faults were related to overheating due to leaf build-up in the heat-sink, the inverter turning off due to grid frequency variation outside its operating range, and faults with inverter control software.

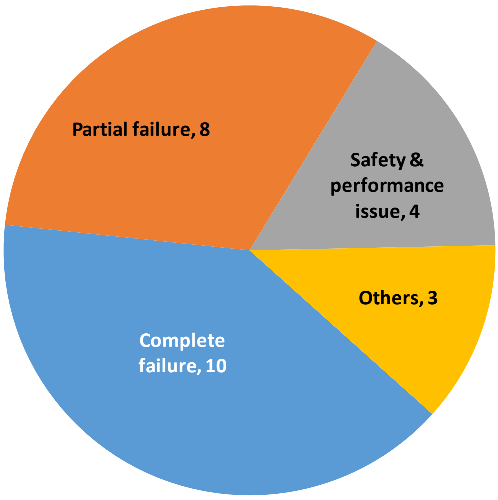

Figure 4: Inverter fault types

Unlike PV modules, there are limited research results available in the public domain that focus on issues and concerns associated with inverters. However, it has been noted that inverters have historically been the leading cause of PV system failures. So there is an urgent need to protect PV systems from unreliable inverters. The information received from this survey further emphasises this fact.

4.4. Other equipment

Other than modules and inverters, PV systems consist of other minor components and fixtures, which should not be forgotten, as faults with these components can undermine system performance or lead to safety hazards. A total of 14 respondents reported faults with other equipment: three faults with rooftop isolators, three faults with the main DC cable, two faults with the mounting structure, two faults with the PV array isolator, two faults with the battery and two faults with the optimiser.

4.5. Installation

While installation should be done in accordance with Australian standards, there were a significant number of reports to the PVFRP in relation to faulty installation of PV systems and components (Table 2). Water ingress into component enclosures and inadequate cable protection are two major issues identified. Safety issues were also reported, for example, inadequate sealing of roof penetrations, incorrect wiring of polarised DC circuit breakers, inadequate earthing of module frames and incorrect rating of components (e.g. cable, fuses and isolators).

Table 2: Faults associated with installation of PV systems

Installation fault type	Number of reports
Water ingress into component enclosures	4
Inadequate cable protection	3
Insufficient array fixing	2
Missing or inadequate documentation	2
Inadequate sealing of roof penetrations (i.e. roof leaking)	2
PV system not allowing roof self-cleaning i.e. build-up of leaves etc.	2
Incorrect wiring of polarised DC circuit breaker	2
Inadequate earthing of module frames	2
Corrosion of equipment due to contact between dissimilar metals	1
Inappropriate location for inverter (i.e. poor access, poor ventilation, exposed to direct sunlight, etc.)	1
Incorrect rating of DC isolators and circuit breakers	1
Inappropriate array location	1
Use of standard multicore TPS cable for DC	1
Incorrect or inappropriate labelling	1
DC and AC wiring inadequately segregated	0
Exposed live conductor	0
Incorrect functional earthing	0
Parallel strings with different number of modules connected in series to the same MPPT or charge controller	0
Insufficient ventilation limiting airflow around modules	0

Similar issues have also been identified by other researchers. The recommendations of a PV systems safety audit, undertaken for a Western Australian Public School in 2011 in accordance with the Australian Standards and the CEC, provide information on a range of issues associated with installation and related services (Calais et al., 2011). Many of the issues are the same as those reported here, for example, inadequate cable protection, missing or inadequate documentation, incorrect rating of component, incorrect or inappropriate labelling and use of standard multi-core TPS cable for DC.

5. Conclusions

This paper has introduced the Australian PV Module and System Fault Reporting Portal and presented some initial findings after five months of operation. Although there are relatively few responses at this stage, preliminary results reveal a similar range of faults reported in PV systems around Australia to other surveys undertaken both nationally and internationally. This indicates that the PVFRP will generate credible data on issues related to PV system reliability and performance. As yet the data do not show any evidence of systematic problems with particular brands of module or inverter. As the portal becomes more widely used and the database increases, it is hoped that any such problems would become evident if they exist. For this reason, the portal will emphasise the importance of users inputting the manufacturer names and model numbers. It is worth noting that a significant proportion of respondents (49%) reported that their issue had not been addressed by the supplier or the manufacturer.

While it is likely that unaddressed problems are more likely to be reported, it should be of concern to the industry if this figure demonstrates a perceived lack of professionalism and ethics by some operators.

Information collected through the PVFRP will be collated and published on a regular basis. Analysis of the types of faults and the geographic regions in which the faults are reported is valuable information for the PV industry and researchers. These data potentially allow some degradation issues to be matched to climatic zones and other regional influences. If sufficient responses can be collected, it is possible that the PVFRP will help identify faults related to Australia's unique climate conditions, which are infrequent elsewhere. A near-term focus of the research team will be making the PVFRP more widely known.

6. References

Bosco, N., 2010. Reliability Concerns Associated with PV Technologies. National Renewable Energy Laboratory, California.

Calais, M., Ruscoe, A., Glenister, S., 2011. Findings and Recommendations from a PV System Safety Audit of 20 Western Australian Public School Installations. Presented at the 49th Australian Solar Energy Society (AuSES) Annual Conference.

Clean Energy Regulator, 2014. Small-scale installation data [WWW Document]. Data Rep. URL http://ret.cleanenergyregulator.gov.au/REC-Registry/Data-reports#Smallscale-installations-by-installation-year (accessed 9.3.14).

Djordjevic, S., Parlevliet, D., Jennings, P., 2014. Detectable faults on recently installed solar modules in Western Australia. Renew. Energy, Renewable Energy for Sustainable Development and Decarbonisation 67, 215–221. doi:10.1016/j.renene.2013.11.036

Kontges, M., Kurtz, S., Pacakard, C., Jahn, U., Berger, K., Kato, K., Friesen, T., Liu, H., Iseghem, M., 2014. Review of Failures of Photovoltaic Modules (External final report IEA-PVPS), IEA PVPS Task 13. International Energy Agency (IEA).

Kurtz, S., Quintana, M., Granata, J., 2009. Photovoltaic-Reliability R&D Toward a Solar-Powered World. Presented at the Society of Photographic Instrumentation Engineers (SPIE) Solar Energy+Technology Conference, San Diego, California.

NREL, 2014. NREL: Photovoltaics Research - Performance and Reliability R&D.

Watt, M., Passey, R., Noone, B., Spooner, T., 2013. National Survey Report of PV Power Applications in Australia - 2013. Australian PV Institute.

7. Acknowledgements

The financial support of the Australian Renewable Energy Agency to undertake this project is greatly appreciated.