Standards development for BIPV

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Abstract - Grid connected PV is being applied in a variety of applications including large centralised stations, commercial buildings and individual houses. Photovoltaic power systems are unique in their characteristics and in their mode of application to buildings. This paper addresses the need for specific Standards to address distinctive new issues created by grid connected PV power systems. Internationally, many countries are attempting to develop Standards for building integration, DC side issues and grid connection issues. This paper surveys the current developmental state of the major countries' Standards in this area, comparing Standards and guidelines under development and highlighting difficult areas of agreement.

1. INTRODUCTION

Greenhouse gas concerns and desires for a more sustainable future are driving a rapidly expanding range of applications of grid connected photovoltaic (PV) power systems. Numerous large-scale projects are currently being commissioned, with more planned for the near future. Prices of both PV and Balance of System Components (BOS) are decreasing following a trend of increased production and improved technology which will lead to further increase in use. With this proliferation of systems comes the need for Standards addressing and thus ensuring issues of safety and quality in manufacture, application and use. Standards will serve to build consumer confidence, reduce costs and further expand PV development.

Frequently, the lack of Standards hampers the development of a technology by allowing extreme cases of application. These extreme cases stem from little and/or incomplete technology knowledge. Possible consequences include over engineering, low installer confidence, extensive one off site testing, commissioning of dangerous technology and unreliable systems prone to failure. These time consuming and expensive consequences result in poor user confidence and market reputation.

Unfortunately, uniform standards are generally difficult to achieve and take a considerable time in the process. The whole PV grid connected building integrated industry is still relatively very young but is expanding and maturing rapidly. The industry spans a large number of disciplines including architecture, electrical engineering, device physics, structural engineering and building trades. This process involves a considerable level of learning and experience that has to be gained by many people as the industry matures.

The other factor that makes these systems unique and standards extremely important is that these systems are connected to electricity utility grids and feed energy back into the grid. Feeding energy into the grid has previously been exclusively controlled and managed by electricity authorities. Electricity grids and their protection systems have been designed around the concept of a relatively small number of large centralised power stations feeding down through a network of high, medium and low voltage systems to the consumer. The concept of having a large number of small PV systems at the consumer end of the networks feeding energy back into the network turns the whole system on it head. This has justifiably set alarm bells ringing and is one of the reasons why guidelines and standards have been required earlier in the evolution of the industry than would otherwise have been in other industries, eg stand alone systems.

1.1 PV Specific Standards

There is a need for Standards to address issues specific to PV applications.
PV generators are unique in their characteristics:

- Unlike conventional grid, PV generators do not have inherently high fault levels.
- The output is not easily turned off and is dependent on a variable environmental resource.
- PV is generally applied to the exterior of buildings or structures and is unlike other building materials.
- It contains cells connected to circuits with potentially dangerous voltages.
- Grid connected PV is a form of distributed generation, interfaced to the grid via inverter systems. These have different characteristics to electro-mechanical generation systems.

1.2 Need for Careful Progression

Electricity utilities are responsible for the safety and quality of supply to their customers. The PV industry needs to be aware of the issues and assist in setting Standards as this will ultimately lead to an increased acceptance of the technology by users and the electricity utility industry.

PV is proving to be a rapidly developing industry. Standards for this reason must be developed cautiously so as to not stifle innovation and growth. It is important to hasten slowly here because a great deal of experience is still being gained with the systems that have been installed particularly on the grid side of the systems. The initial reactions of electricity utilities faced with this technology feeding into the grid, was justifiably very cautious. This led in some cases to complicated and expensive requirements being placed on connections. Once a requirement is put in place it is often very hard to downgrade or remove it particularly when it reaches the status of a standard. It is important to put in place as many standards as we can for these systems where the requirements can be readily agreed. Where there is still a significant debate (eg the islanding issue) there has to be still a period of learning and data collection with reasonable levels of protection and safety without draconian measures (which add unreasonable costs to the system) totally stifling the ability of the industry to compete.

2. MAJOR DC SIDE AND GRID CONNECT ISSUES

2.1 DC Side Issues

- Protection of humans from electric shock: - Insulation type; Fuses; Grounding; Warning signs; Equipment mounting; Limited site access.
- Wiring system: - Temperature ratings; environmental protection (Eg. UV exposure); Insulation (self-extinguishing preferable); DC wiring practices (as opposed to AC practices).
- Protection of equipment and surroundings from fire hazard due to equipment failure (Eg. overload, short circuit, over voltage)
- Requirements for equipment and components: - Terminals; junction boxes; Switch gear on DC side (Eg. circuit breakers, fuses) rated for DC.

2.2 Grid Connect Issues

- Islanding protection:- Passive (over/under V & f); Active (Eg. frequency drift, impedance).
- Quality of supply: - Harmonics; Flicker; Overvoltage from direct/indirect lightning and transient overvoltage in grid; DC injection: EMC – EMI.
- Reverse power flows:- Grid capacity; Metering; Buy back
- Grid supply availability for periods of low/insufficient irradiance
- Short circuit capacity • Auto reconnect after trip • AC side disconnect switch
- AC modules

2.3 Priority Issues

The priority areas for any standards have to be in the area of safety.

2.3.1 DC Safety

DC voltages of grid connected systems are now commonly above 120V in an effort to achieve energy efficiency and cost effectiveness in the inverter systems. In some systems the voltages are going beyond 600V DC. This highlights the need for standards addressing, safety of the installation with respect to contact with dangerous voltage levels. This includes warning signs, limiting access, insulation and grounding.

In the important DC area of grounding and protection, which are obviously inter-linked, there appears to be basically two approaches: The US approach and the European approach. The US requires grounding of the array and automatic interruption of the DC under fault conditions. The European approach allows for an isolated array with detection of an earth fault. Both approaches have their pros and cons but are philosophically different.

2.3.2 Grid Interface

In the area of the grid interface, the most difficult questions relate to islanding and it appears that there are many questions still to answer, particularly when the penetration level of systems becomes significant. There is a need to carefully define the test circuit and procedure for testing an inverter for islanding protection performance [12]. There has been a progression from simple local load requirements to resonant circuits and fixed embedded sources [16] and to requirements for multiple inverter testing [17, 18]. As can be seen in [16] there are a number of possibilities if a single inverter test is required and many more possibilities when multiple inverter tests are considered [17,18]. It is an area of significant international debate and has been for a number of years. Until a significant amount of real operational data is obtained, it will be very difficult to obtain uniform international standards on the question of islanding. Many of the other issues are of much less significance and international agreement should be achievable.

3. INTERNATIONAL STANDARDS

Internationally the area of PV Standards is in its infancy. There are a number of Standards existing, (see bibliography) with a number of new standards under development in working groups and committees. Our website: http://ee.unsw.edu.au/~std_mon/ contains comparison tables of 'DC Side Issues' and 'Grid Connect Issues'. In the area of grid interface connection issues, IEA PVPS task V has produced three very useful documents [12,13,14]. IEA [13] summarises the various guidelines in selected IEA member countries. A comparison table of guidelines is also included on the web site.

IEA [12] provides background to the main issues addressed in various guidelines. These guidelines are a very valuable pre-cursor to Standards as they are dynamic, adaptable and grow with field experience. Initially PV standards issues have been addressed in sections of wiring codes [1,3]. Standards addressing specific issues [2,4,5,6,7,8,9] are also progressing, with the US taking a significant lead with component and system standards [4,5,7].

IEC photovoltaics committee TC82 and the main wiring rules committee TC64 are cooperating to revise the wiring rules document [1] and new documents for inverters and charge controllers are being developed based on the UL1741 document. Grid connection guidelines are also under discussion and a special committee is being convened to attempt a better resolution of the differences between member country requirements. The main issue of significant difference is the one of islanding protection, with considerable differences among German, Japanese and other countries' approaches.

4. AUSTRALIAN REQUIREMENTS

4.1 Guidelines and Standards

Australian guidelines, [11] address grid connect issues only and do not attempt to cover DC side issues. AS3000 [10] does not cover PV specific issues. There is a need for either sections in AS3000 dedicated to PV (Eg. as per NEC, IEC 60364) or a separate supplementary document emphasising PV specific DC issues as opposed to familiar and traditional AC issues.

The task of translating existing non-PV specific electrical codes to PV installations is not trivial. Sandia National Laboratories recognises this and have produced a document called “Photovoltaic Power Systems and the National Electrical Code: Suggested Practices” aimed at complementing the NEC. Australia would benefit by a similar document.

Australian Standards committee EL/42 is currently working through a subcommittee to move the existing "Australian Guidelines for Grid Connection of Energy Systems via Inverters" into an Australian Standard. There has been almost universal acceptance of these guidelines by electricity utilities in Australia. Other countries have also copied sections of our guidelines. The EL42 committee will also start to look at the DC side issues for Australia with careful regard to Australian climate conditions, building styles and developments in the international area. There is also an urgent need to provide guides and information for builders and architects with respect to PV systems.

4.2 Testing and Approval

Australia needs to put in place a clear test and approval process for grid connected systems. At present testing of inverter systems to the Australian Guidelines is generally carried out at The University of New South Wales by the author working as part of ACRE standards and testing, at our Energy Research Facility at Little Bay. (Later this year a new testing laboratory for renewable energy systems ACRELab situated in Perth will be fully operational and will assist by providing expanded test facilities.)
After testing is complete a report is supplied to the manufacturer or supplier of the inverter equipment. This report is then submitted to the local supply authority when an application for connection is made. This process has worked well and is generally accepted but the reports have no official status and there is no clearly defined

formal or centralised "approval" process. Creating an official process that was uniform across Australia would further assist the adoption of this technology.

5. CONCLUSION

Internationally, guidelines and Standards for grid connected PV systems are in early stages of development but rapid progress is occurring. The current lack of Standards is causing cost increases and delays in the implementation of new PV projects. It is important that we hasten the process of standards and guideline development but with great care not to stifle industry development and innovation.

The tables that are downloadable from our web site it is hoped are a valuable resource. It is hoped that these will assist future Standards development. Much valuable work has already been done but more needs to be accomplished with as much commonality between country's Standards as possible.

The highest priority area is safety, particularly on the DC side where DC voltages above 120Vdc are becoming common. The other major safety issue is the area of islanding where there is considerable disparity amongst different country's requirements.

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