Challenges of an emerging PV industry

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Overview

- Growth of the industry
- Technical issues
  - Focus on grid connect
  - Just a sample of some significant ones
- Standards Issues
Wide Range of Installations
Commercial Buildings
Architectural Shading
Kogarah Town Square

30/01/2003
Nyngan 102MW - AGL
Cumulative Installed PV power

Figure 1: Evolution of Cumulative PV Capacity (MW)

Source IEA PVPS “Trends in Photovoltaic Applications Rep IEA-PVPS”
Figure 6: Evolution of Grid-Connected PV Market Segmentation

Source: IEA PVPS “Trends in Photovoltaic Applications Report” IEA-PVPS
Figure 15: Evolution of Cell Production in Selected Countries – 2008/2012 (MW)

Source: IEA PVPS “Trends in Photovoltaic Applications Rep IEA-PVPS
Figure 21: Theoretical PV Electricity Production Based on Installed Capacity End 2012

Source IEA PVPS “Trends in Photovoltaic Applications Rep IEA-PVPS"
Australian Electricity Networks

- Currently 2.7GW PV on S.E. network
- PV - single largest generator
  - if taken as an aggregated source.
- PV connected increasing at 10-20MW/week!!
In a perfect world ....

Get support/regulated in place early:

- Standards
  - Funding?
- Regulation
  - Licensing/Accreditation
  - Product testing/approvals
  - Auditing
- Training
  - Installers
  - Emergency Services
In the real world...

- Industry growing and innovating RAPIDLY
- Standards take time
  - inevitably playing catchup.
- Regulation has limited resources
- Training
  - Needs more resourcing/coordination
Safety Issues
"THAT'S OK....I CAN HOOK IT UP MYSELF!"
PV Arrays - different to the usual house wiring!

- dc wiring
  - unfamiliar territory for many electricians
  - Arc faults a problem even at relatively low dc voltages.
  - Requires properly rated d.c. components
- PV is a current limited source!
- PV arrays are not readily turned off.
- Distributed over an area
  - on an array frame, roof or exterior surface.
  - exposed to rain, extreme temperatures and ultraviolet radiation.
System Configurations

- Wide range of d.c. Voltages up to 1kV
- Many PV arrays - Transformerless inverters
Protection of Strings in current limited Arrays
Fuses

Example

\[ I_n = 1 \]

\[ I_{nf} = 1.13 \times I_n \]

\[ I_f = 1.45 \times I_n \]

\[ n_p = 5 \]

Fuse Ratings for PV protection

- No definite time blow
- Inf
- \(-I_n\)
DC Arcs in PV arrays
What types of situations?

- Parallel arc
- Earth fault
- Series arc
JB in multi megawatt PV power plant.
DC Switch/Isolators
Arc Fault in Double Pole DC Sub-Array Switch
Series Arc Fault - Single String

Insert here an IV characteristic showing available arc voltage under each condition.
New Standards needed

ARC DETECTION

SWITCH

- PV switches - difficult environmental conditions
  - Temperature extremes
  - Thermally cycled daily
- Not operated often.
  - Contact resistance
- No fault current
  - Issues also at low operating current
Building Integration

- Mounted on/in buildings
  - need BCA guidelines
- Mounting, wind loading
- Wire routing in buildings
Fire Fighters
Fire Fighter Issues

- Shutting down a system
- Spraying water on live arrays
- Standing water
- Entering a building with a live array on roof
  - Wires hanging down
  - Arcs
  - Protective clothing
Flood Safety

- Electric Shock
- Fires
- High Water Issues
- After the water has receded
Mechanical Security
Consequences?

Glass failure

- Falling debris most serious consequence?

More serious for some locations and types of installations?
Grid Connect

- Protection
- Islanding
- Voltage regulation & Power Quality
- Microgrids/Smart Grids
- Energy Storage
Islanding Event - Spain
FAILURE OF ANTI-ISLANDING PROTECTIONS IN LARGE PV PLANTS

➢ In both cases long duration islands have been reproduced (600 kW to 2.5 MW)

TIME PLOT - RMS U, CH1
8.00 V/div
MIN MAX AVE

Island finished, breaker open

Substation breaker closed

Substation breaker open

ISLANDING BEHAVIOUR

Substation breaker closed

13 minutes island (intentionally finished, so it could be longer)
Figure 2: Overvoltage leading to revenue meter damage during LV switching-off (voltages and currents)
Developments

- INVERTERS
  - Module inverters
  - IR measurement / earth fault alarms
  - VAr compensation
  - Fault ride through

- OTHER
  - Protecting & shutting down PV
    - Active Junction boxes
  - D.C. Arc detection
Standards - Where are we?

- Australian Standards for Grid Connected PV:
  - AS/NZS 5033 “Installation of PV Arrays”
  - AS/NZS 4777 “Grid connection of energy systems via inverters”
Standards

- International
  - Module performance and safety standards
  - Installation Standards & BIPV
  - PV Inverter safety standard IEC 62109
  - Arc Detection
  - Fuses IEC 60269-6
  - Connectors EN 50521
  - Cables – new IEC coming
  - Other BOS component standards
More Needed

- Emergency shutdown at module level
- Standards for systems with Storage
- Better power electronic standards for new components
  - DC switches for PV
  - Micro-Inverters
  - Charge controllers
  - Components near PV arrays
  - PV module shutdown
  - DG control standards for grid regulation & control
Simple? PV System

- Solar Modules
- Micro Inverters
- Roof-Top DC Isolator
- DC-DC
- Smart Grid
- Grid Protection
- VAr & Power Control
- Overcurrent Protection – Fuses?
- Isolation / Separation???
- Transformerless?
- ARC Detect
- Insulation R & RCD detection
- Smart Modules
- DC Isolator
- Inverter
- Switches
- Switches
- Overcurrent Protection – Fuses?
Standards Issues

• Lot to do!
• Long development time for each standard
• Done by volunteers
• Many issues across multiple committees
• Standards not seen as sexy, cool, hip!
• Not much government support
In Rapid Growth -

Need rapid development &

Rapid update of all support systems.
Questions???