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

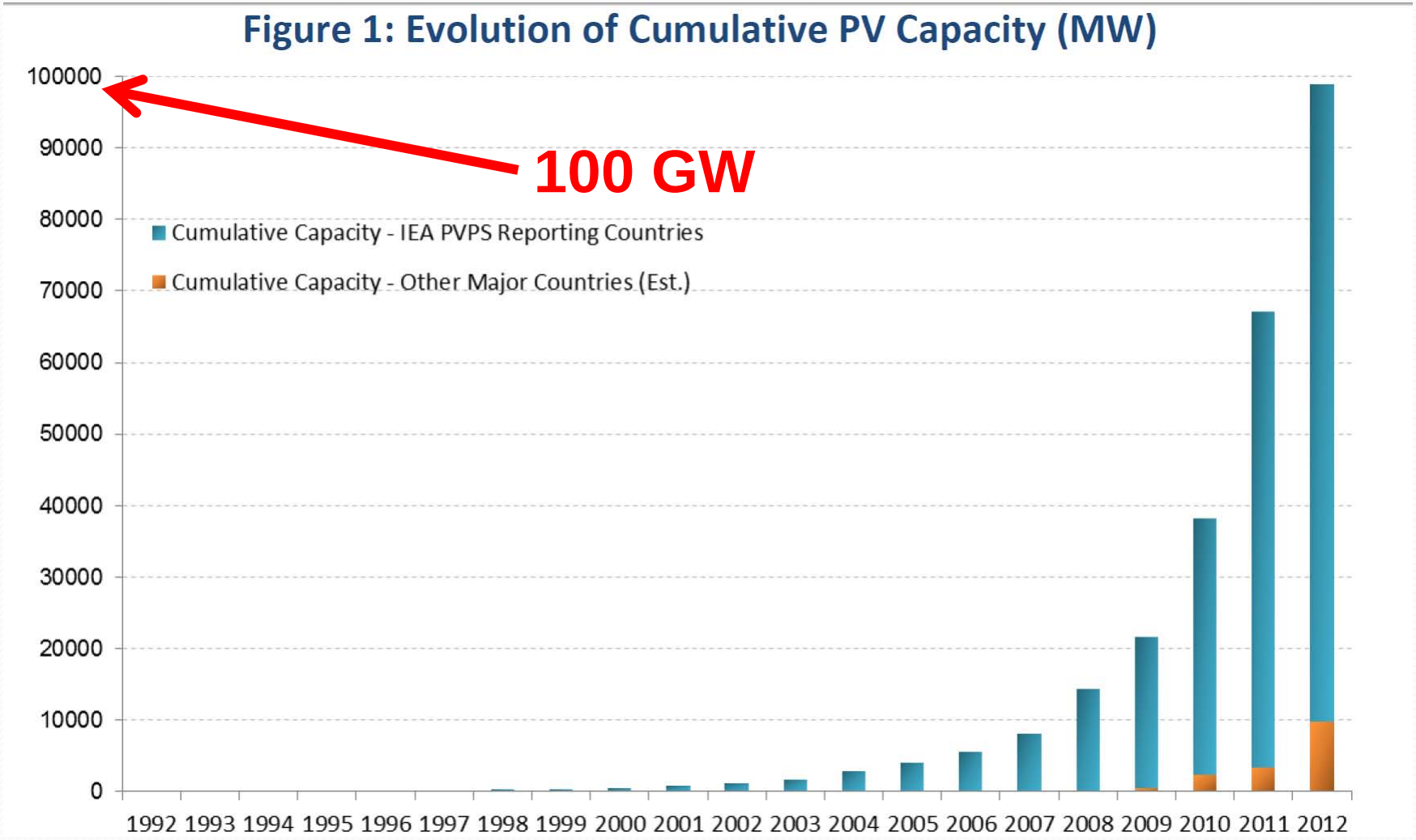
Commercial Buildings

Architectural Shading

Kogarah Town Square

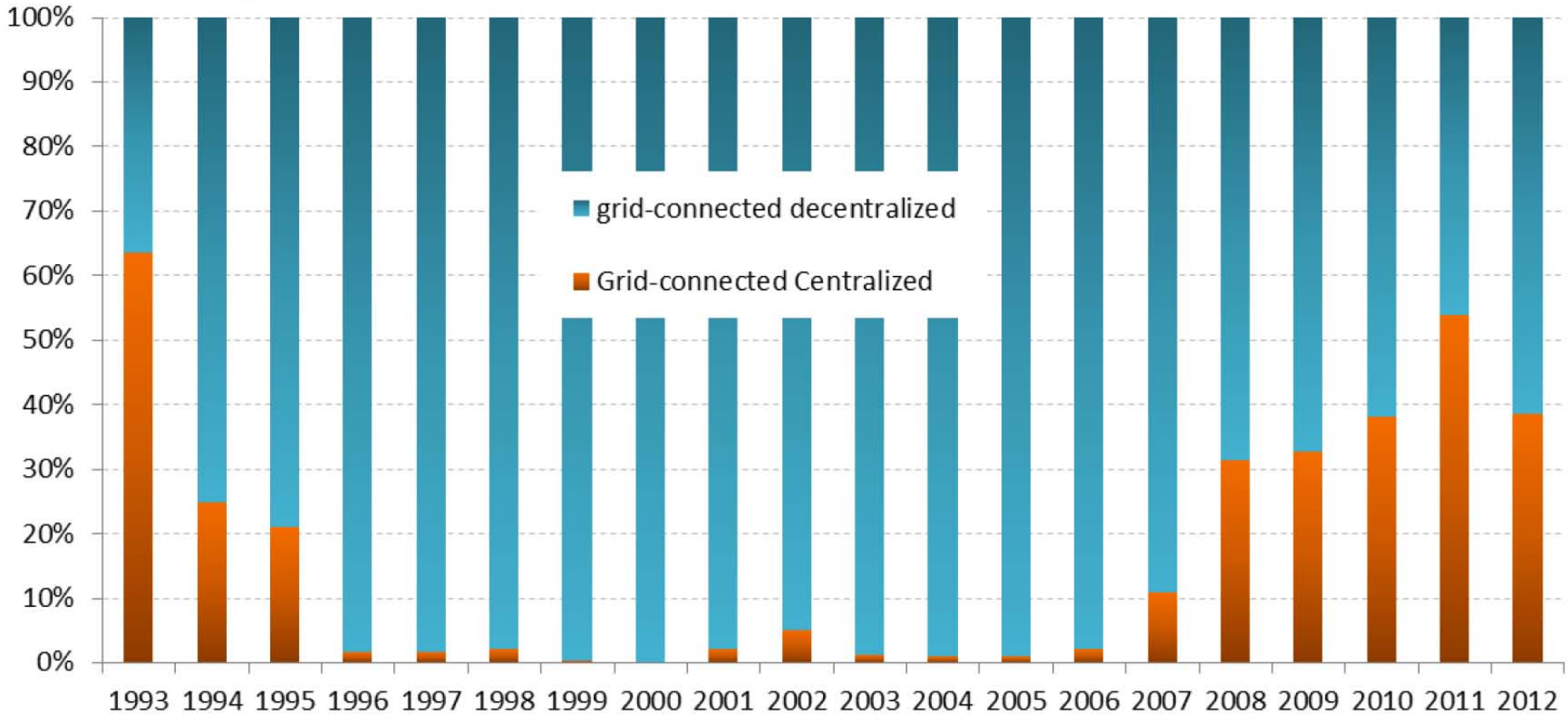
Nyngan 102MW - AGL

Cumulative Installed PV power



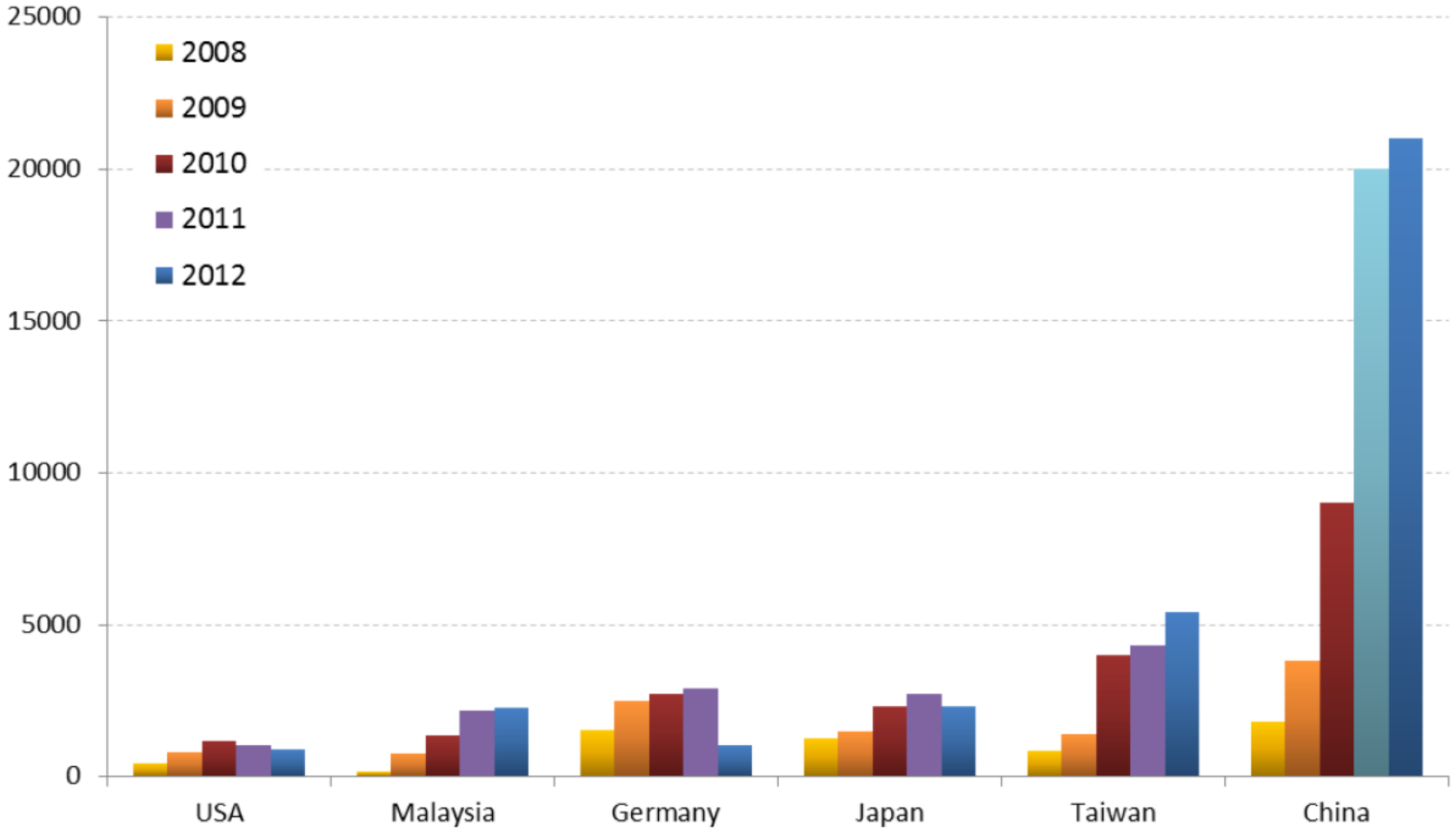
Source IEA PVPS "Trends in Photovoltaic Applications Rep IEA-PVPS"

Figure 6: Evolution of Grid-Connected PV Market Segmentation



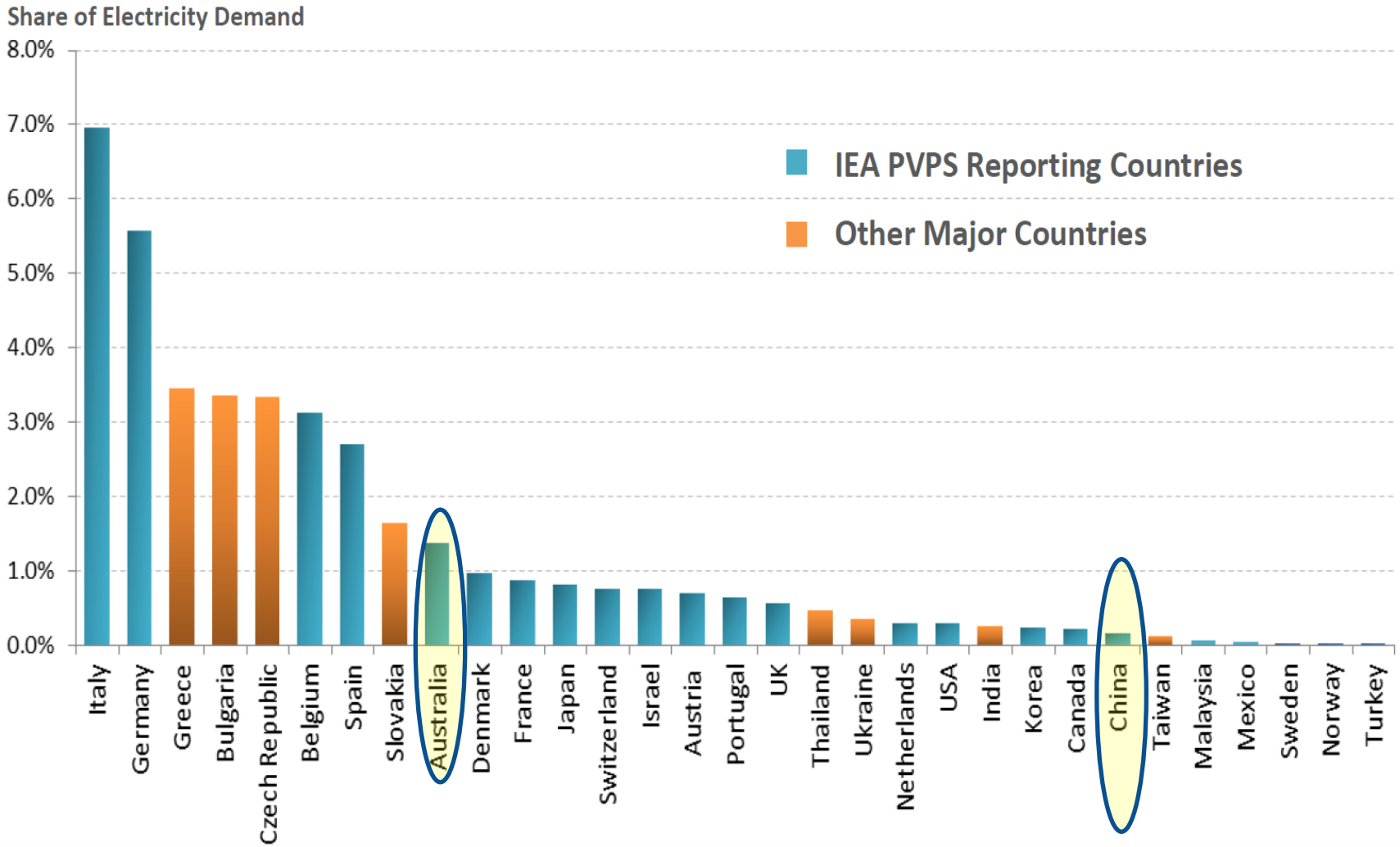
Source IEA PVPS "Trends in Photovoltaic Applications Rep IEA-PVPS

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/regulation 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

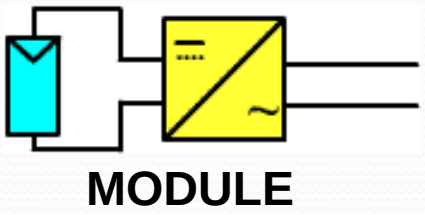

"THAT'S OK....I CAN HOOK IT UP MYSELF!"

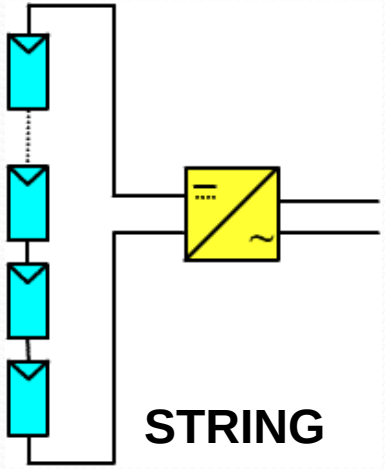
PV Arrays - different to the usual house wiring!

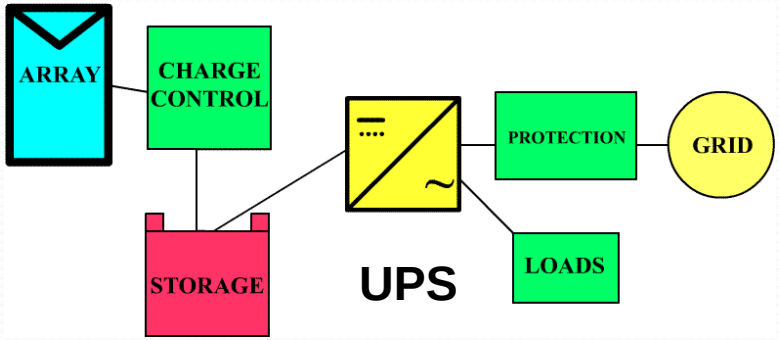
- dc wiring
  - unfamiliar territory for many electricians
  - Arc faults a problem even at relatively low dc voltages.
  - Requires properly rated d.c. components
- PV is a current limited source!
- PV arrays are not readily turned off.
- Distributed over an area
  - on an array frame, roof or exterior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

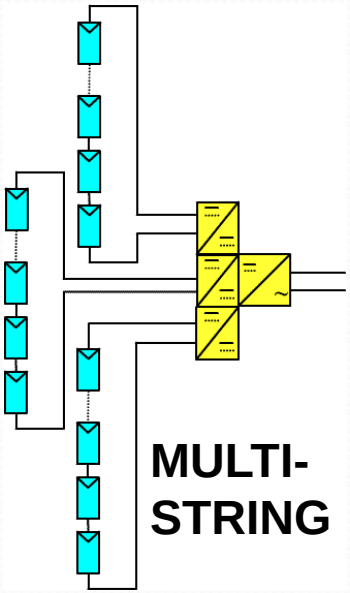
System Configurations

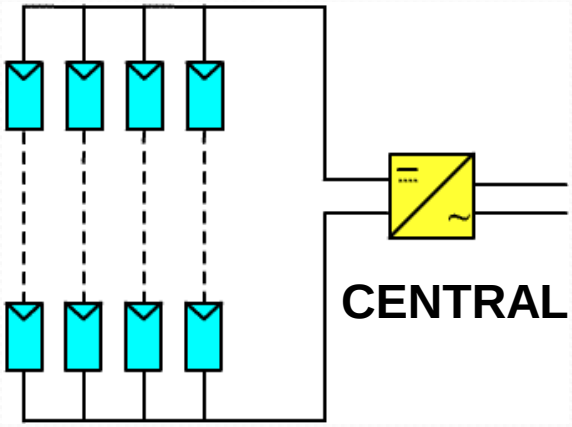
- Wide range of d.c. Voltages up to 1kV
- Many PV arrays -Transformerless inverters

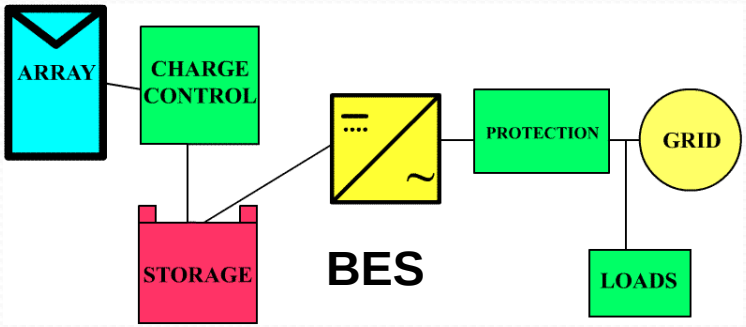




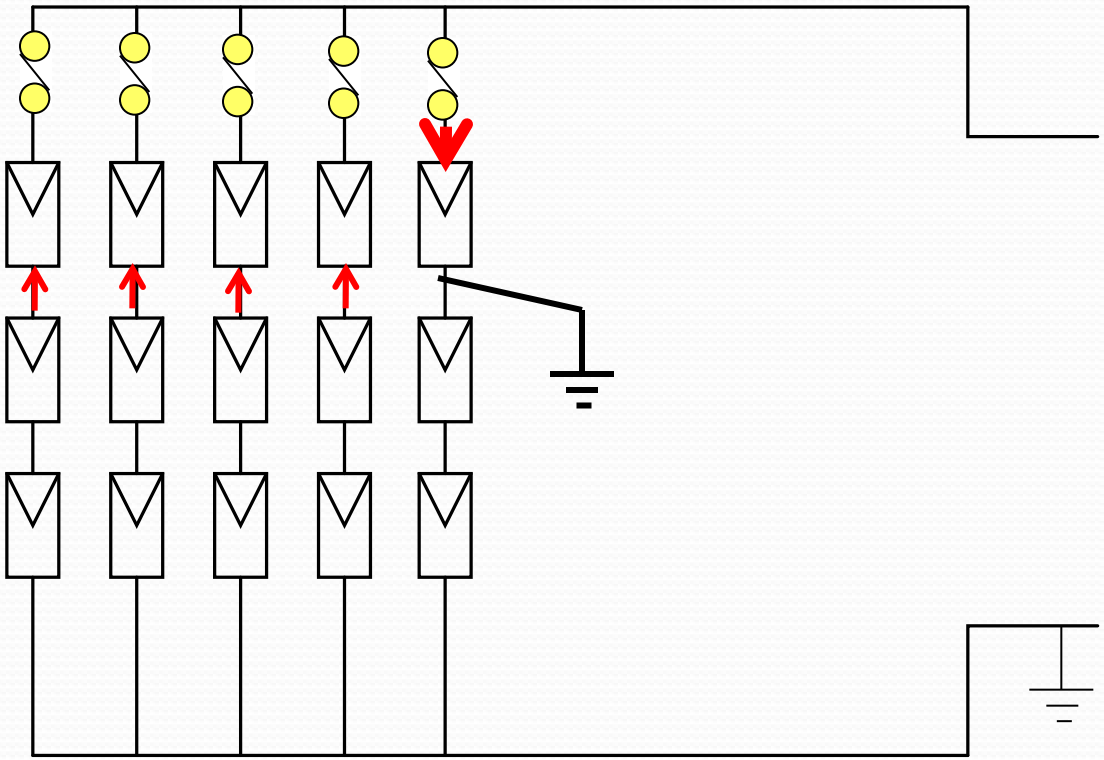








Protection of Strings in current limited Arrays



Fuses

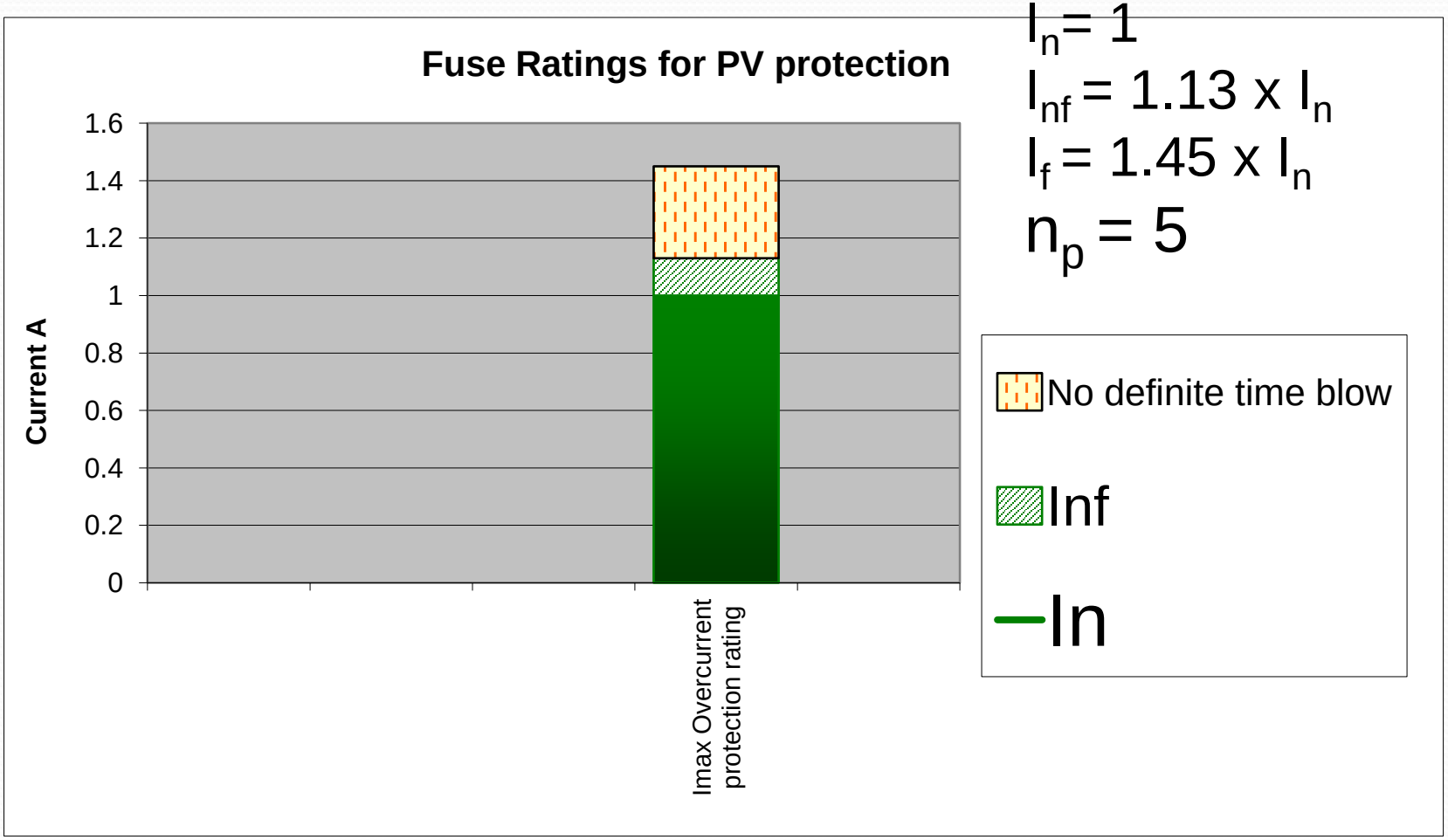
Example

$I_n = 1$

$I_{nf} = 1.13 \times I_n$

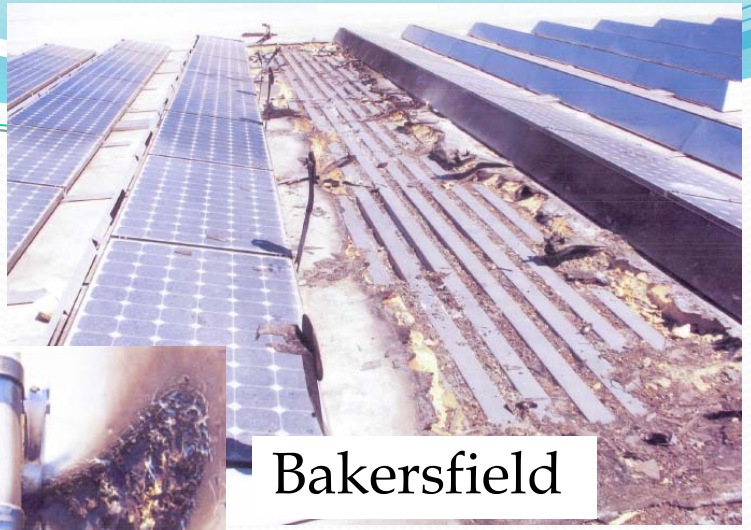
$I_f = 1.45 \times I_n$

$n_p = 5$



d.c. Arcs & Fires

Coffin Bay SA

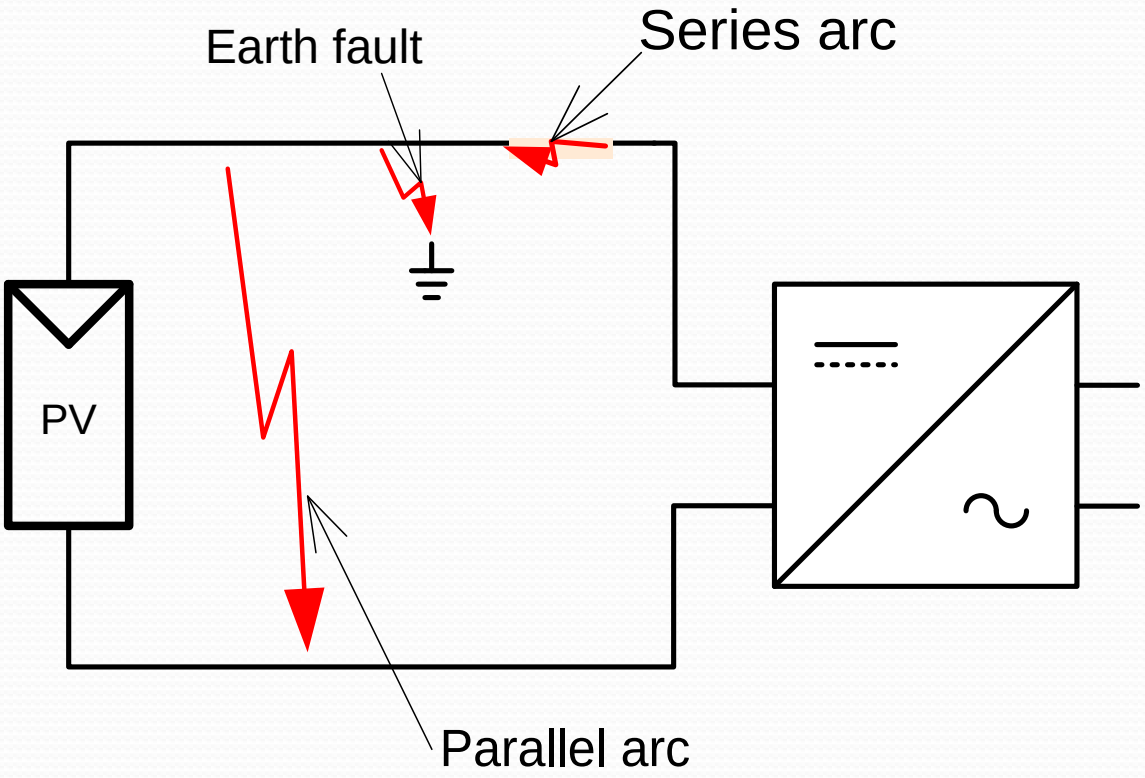


Bakersfield

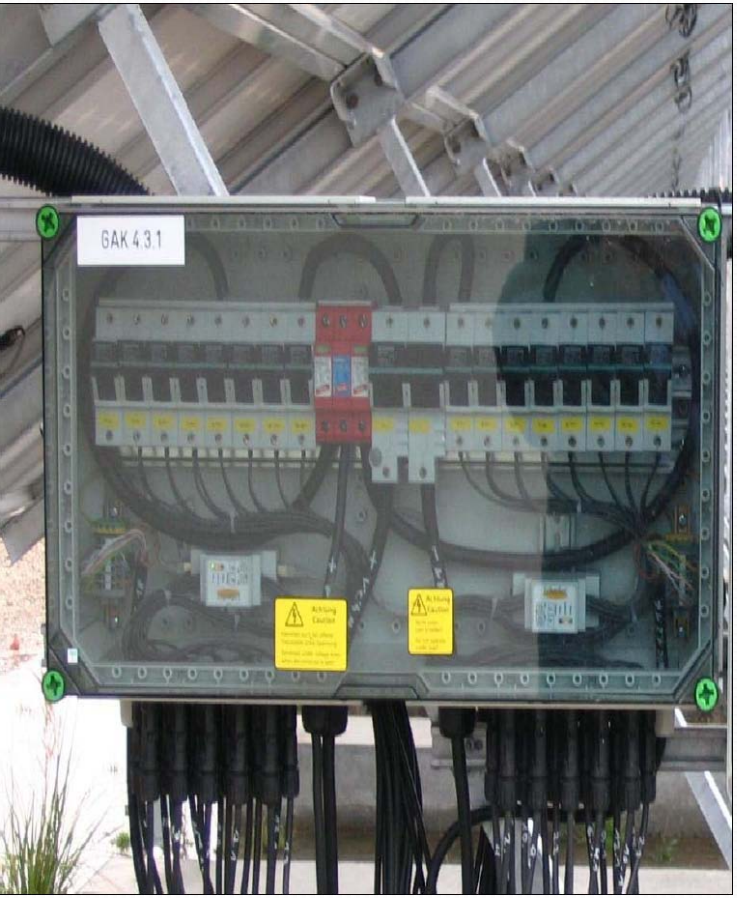
Buerstadt

House in USA

DC Arcs in PV arrays
What types of situations?



JB in multi megawatt PV power plant.

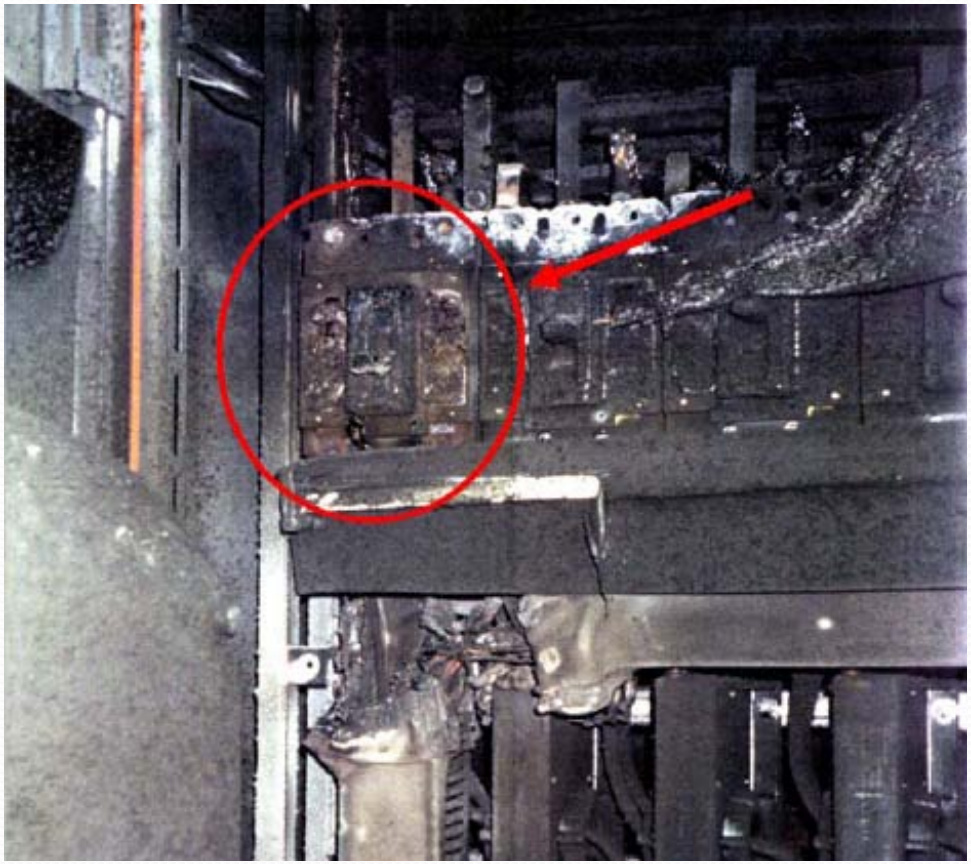


BEFORE

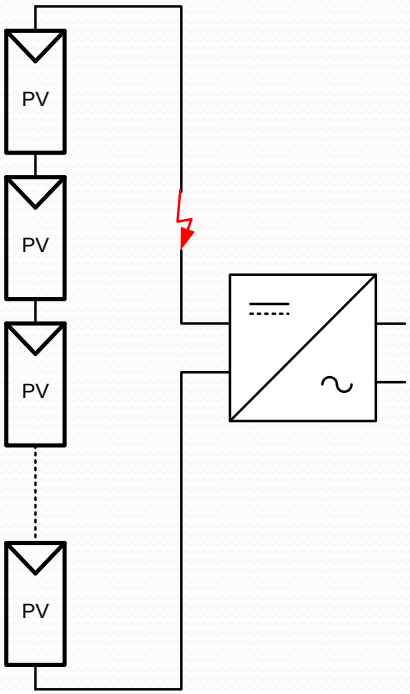
AFTER

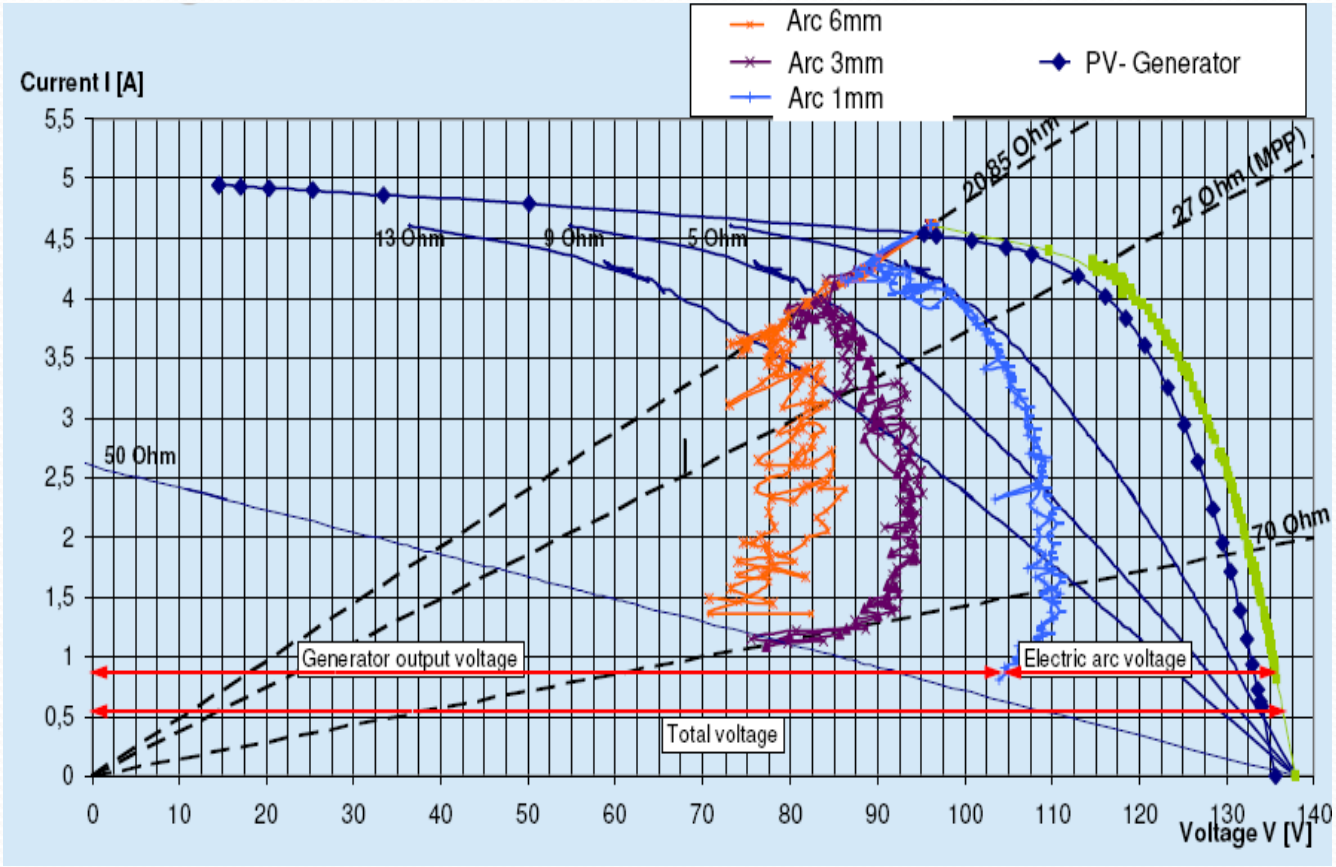
DC Switch/ Isolators

Arc Fault in Double Pole DC Sub-Array Switch



Series Arc Fault - Single String





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

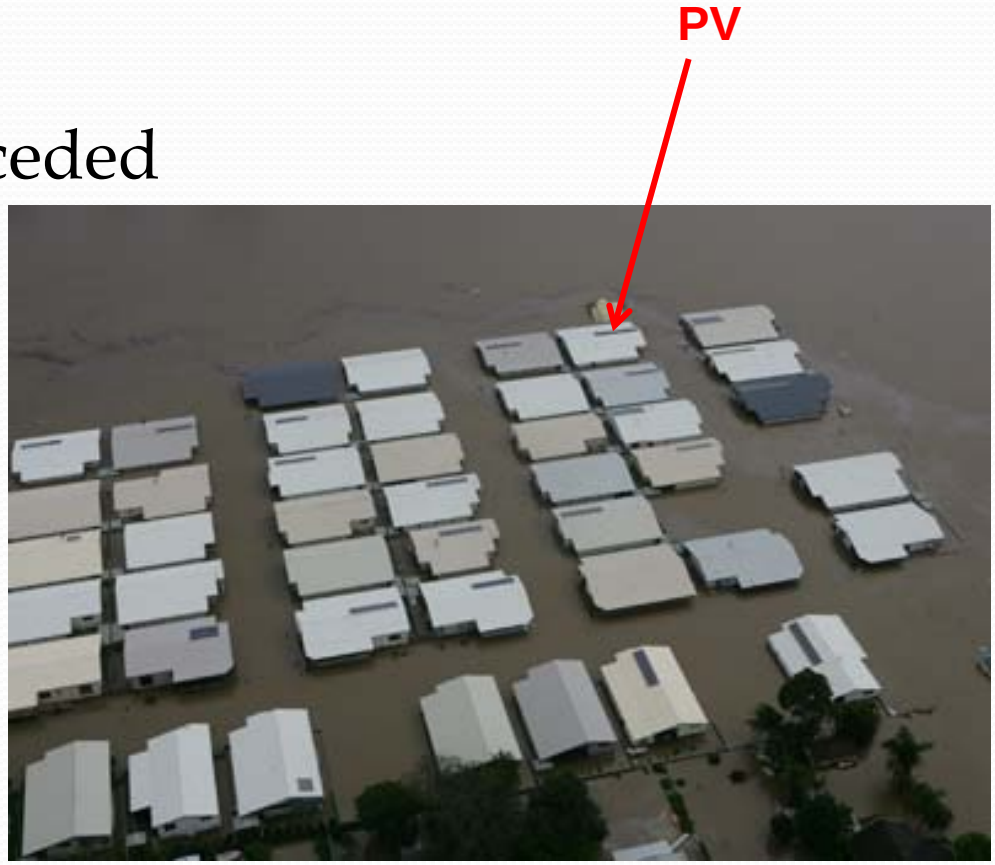
Fire Fighters

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 failiure

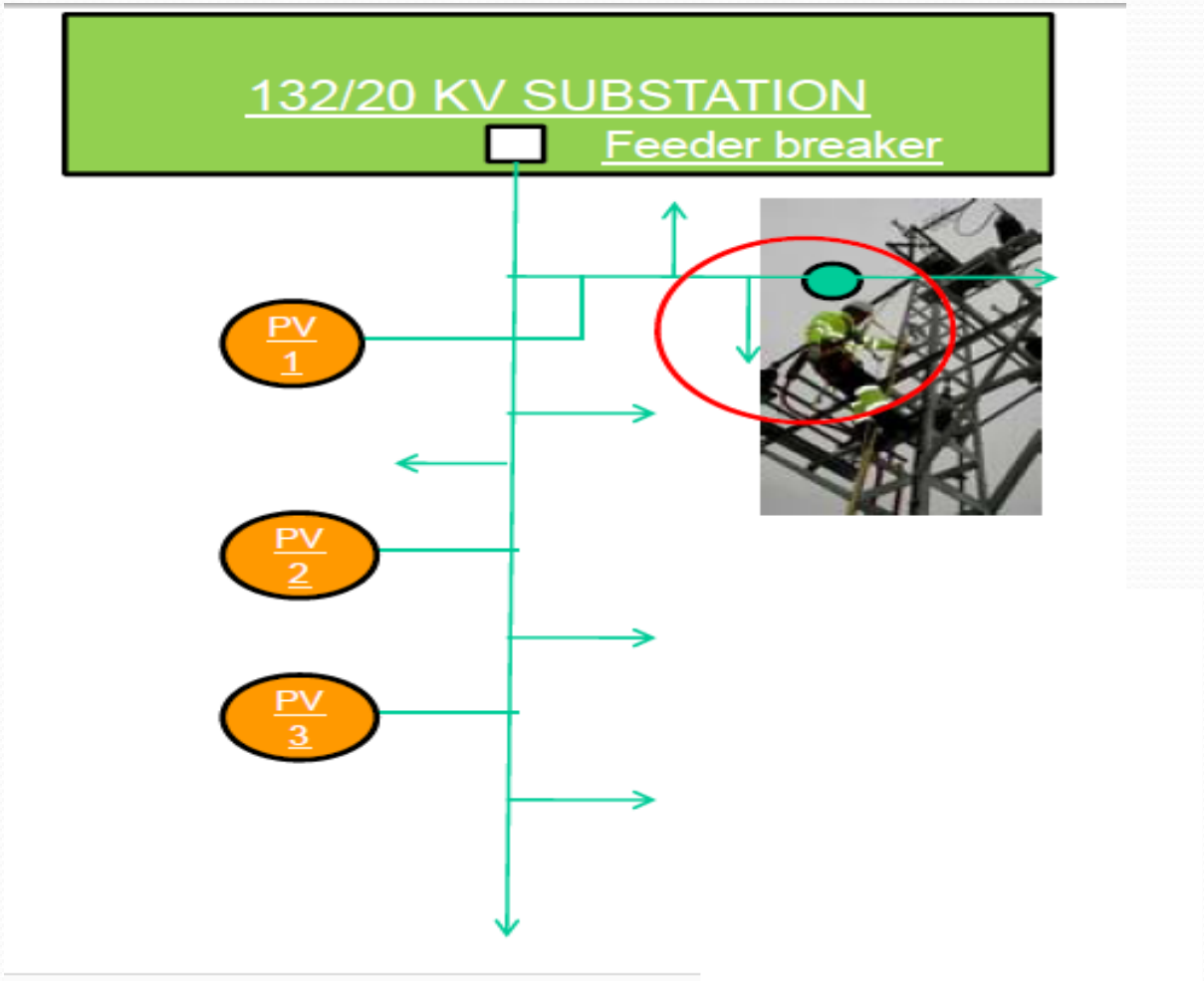
- Falling debris most serious consequence ?

More serious for some locations and types of installations?

Grid Connect

- Protection
- Islanding
- Voltage regulation & Power Quality
- Microgrids/Smart Grids
- Energy Storage

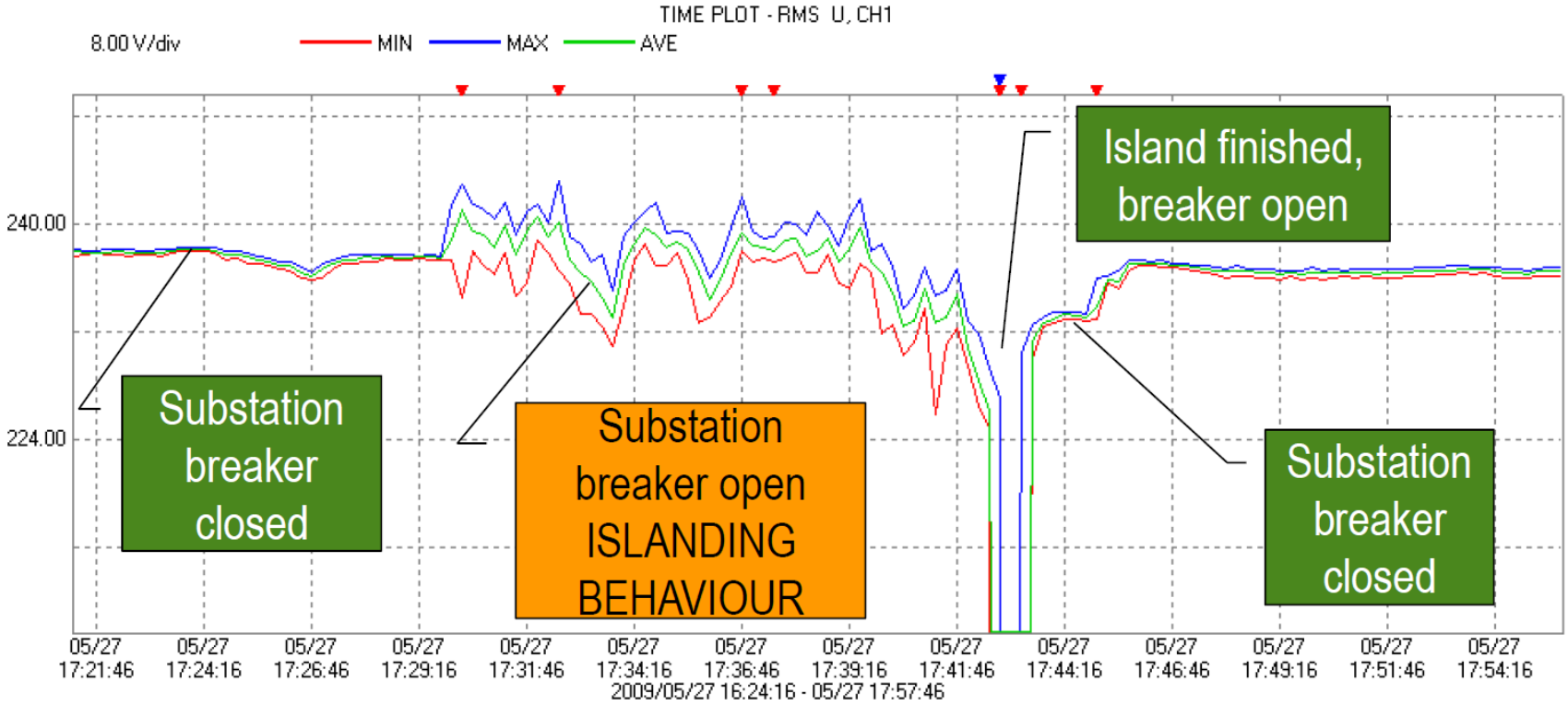
Islanding Event - Spain



FAILURE OF ANTI-ISLANDING PROTECTIONS IN LARGE PV PLANTS

IBERDROLA

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



13 minutes island (intentionally finished, so it could be longer)

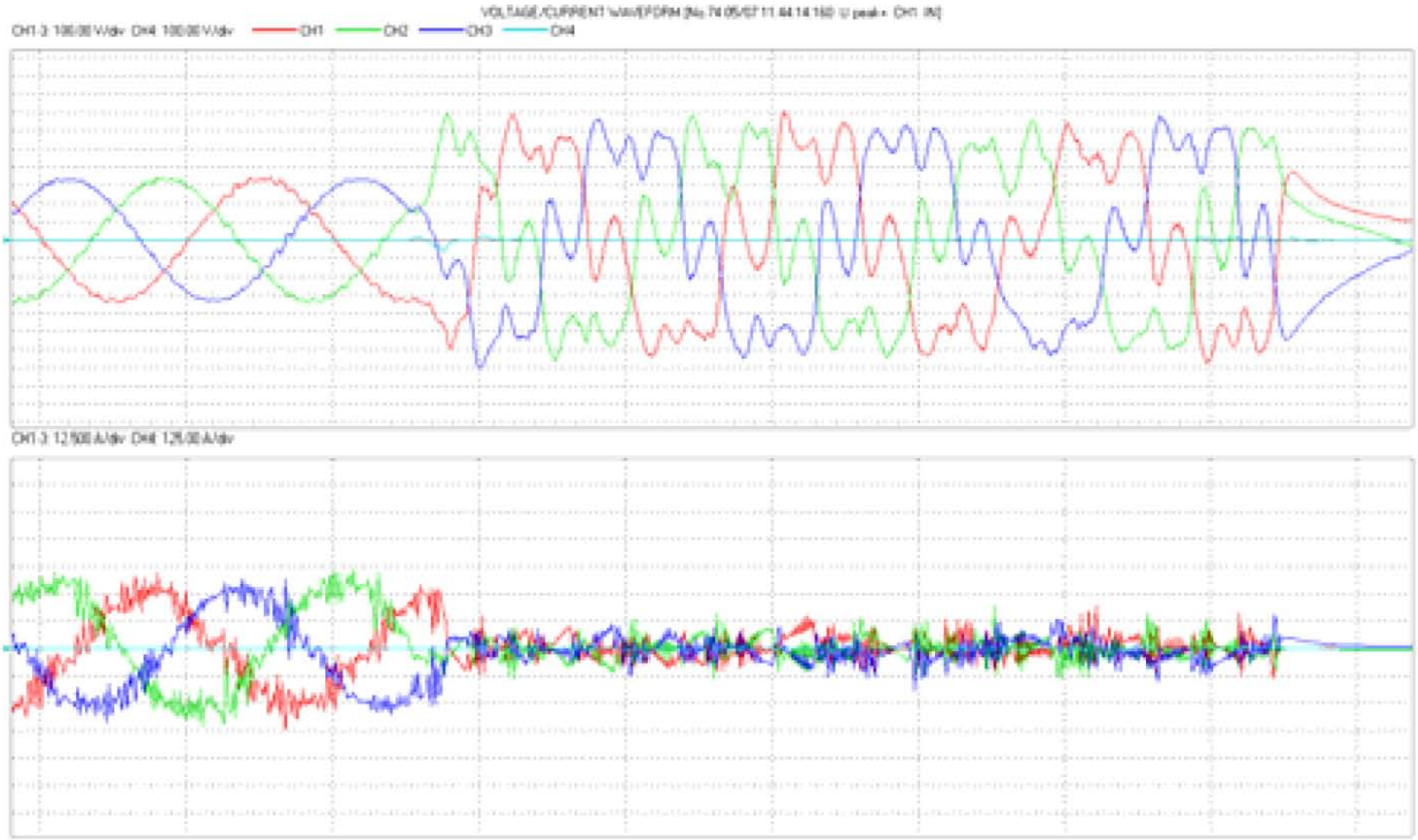


Figure 2: Overvoltage leading to revenue meter damage during LV switching-off (voltages and currents)

“ **POWER FREQUENCY OVERVOLTAGES GENERATED BY SOLAR PLANTS** “
C I R E D 20th International Conference on Electricity Distribution Prague, 8-11 June 2009

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

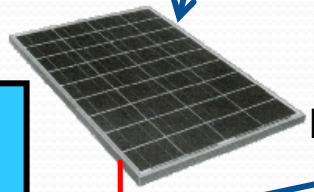
- International
  - Module performance and safety standards
  - Installation Standards & BIPV
  - PV Inverter safety standard IEC 62109
  - Arc Detection
  - Fuses IEC 60269-6
  - Connectors EN 50521
  - Cables – new IEC coming
  - Other BOS component standards

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

Smart Modules



Micro Inverters

Sola Modul

DC-DC

Overcurrent Protection – Fuses?

Roof-Top DC Isolator

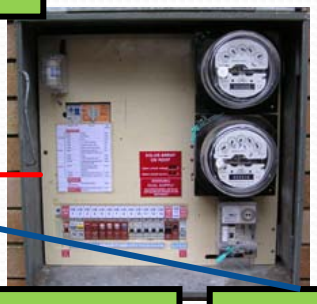
Insulation R & RCD detection

Isolation / Separation???

Switches

ARC Detect

Smart Grid



DC Isolator

Inverter

Transformerless?

Grid Protection

VAr & Power Control

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???