Introduction on technical guidelines for utilities integrating PV into their grids

Palau Workshop
8th-12th April

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Session Overview

- What Guidelines?
- What standards?
- What is a grid connected PV system?
- Issues?

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SEIAPI & PPA Guidelines

- Released September 2012
- Include:**GRID-CONNECTED PV SYSTEMS** (No Battery Storage)-
  - SYSTEM INSTALLATION GUIDELINES
  - SYSTEM DESIGN GUIDELINES

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Standards-Aust/NZ

- AS/NZS 3000 Wiring Rules
- AS 4777.1 Grid connect - Installation
- AS/NZS 5033 Installation of Photovoltaic (PV) Arrays
- AS/NZS 1768 Lightning Protection
- AS/NZS 4509 Stand-alone Power Systems
- AS/NZS 3008 Selection of cables
- AS/NZS 1170.2 Wind Loads

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Standards-USA

- Electrical Codes-National Electrical Code Article 690:Solar Photovoltaic Systems and NFPA 70 Uniform Solar Energy Code
- Building Codes- ICC, ASCE 7
- UL Standard 1701; Flat Plat Photovoltaic Modules and Panels
- IEEE 1547, Standards for Interconnecting distributed Resources with Electric Power Systems
- UL Standard 1741 , Standard for Inverter, converters, Controllers and Interconnection System Equipment for use with Distributed Energy Resources

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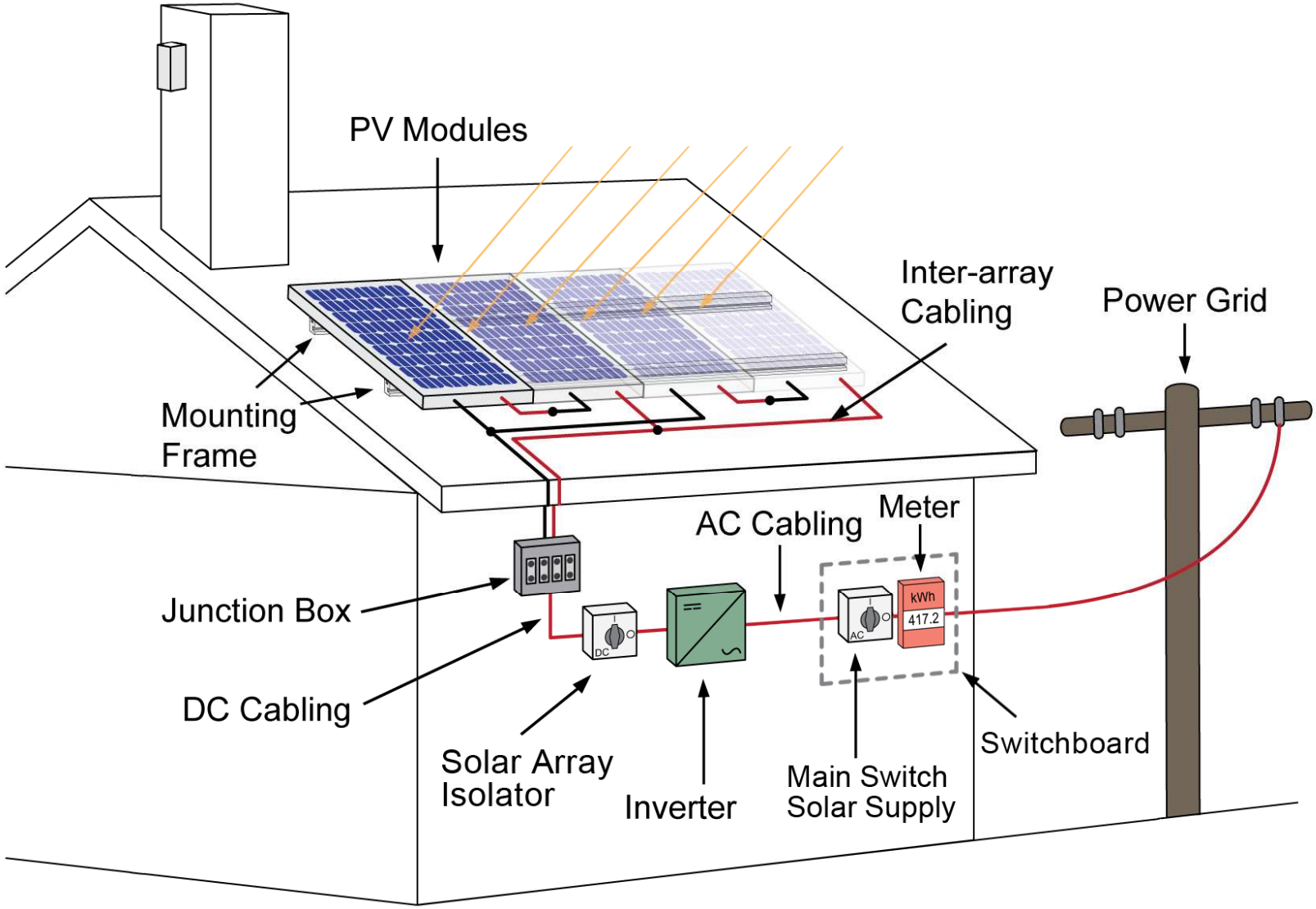
What is a grid connected system ?



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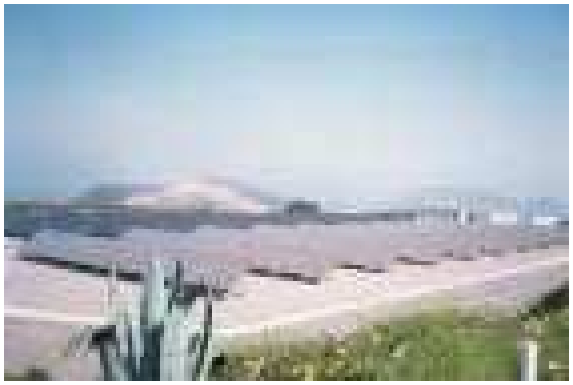
Types of Grid-connected PV systems

grid-connected systems

Centralized

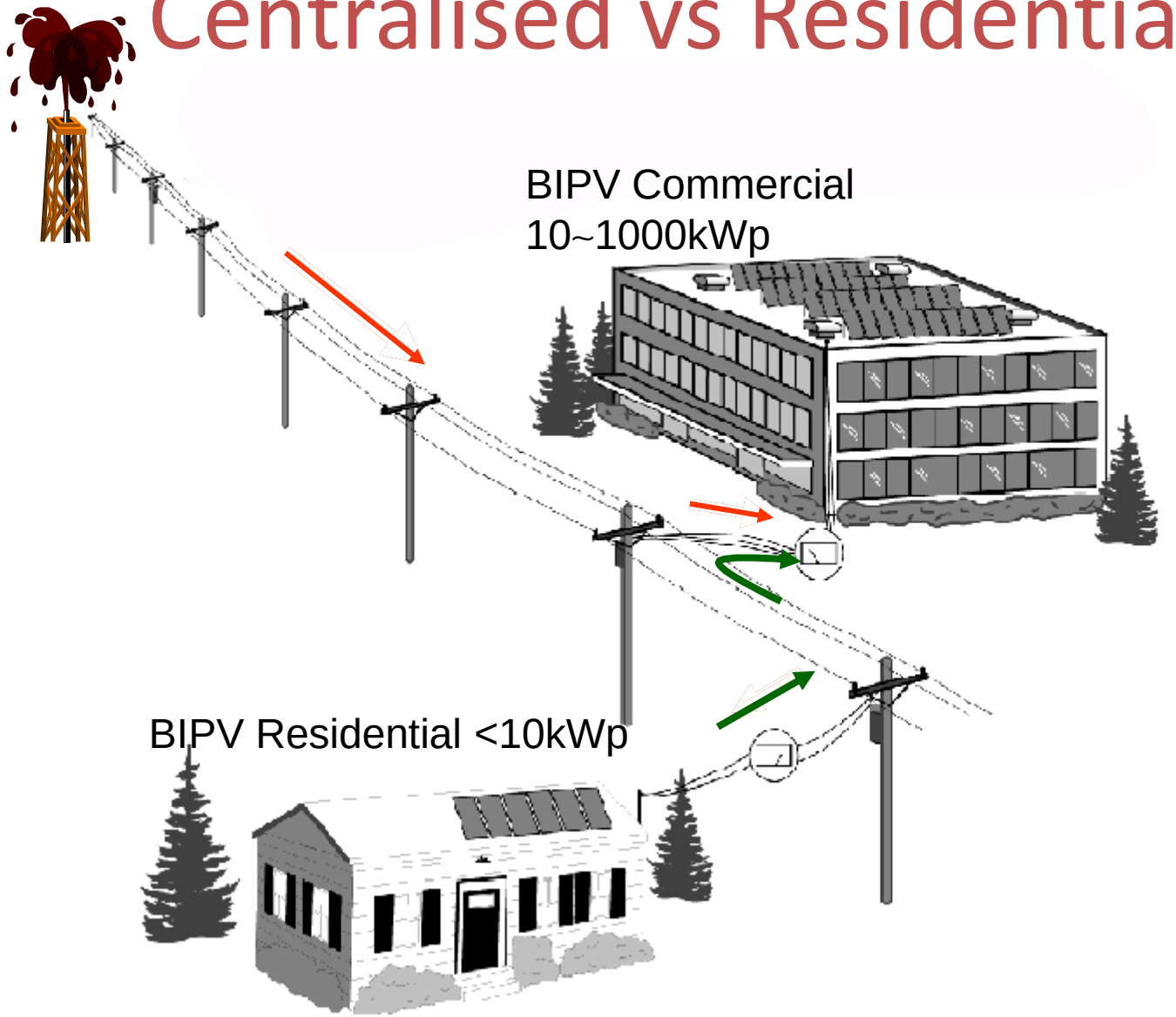
- directly connected to the public grid



- connected to public grid via house grid

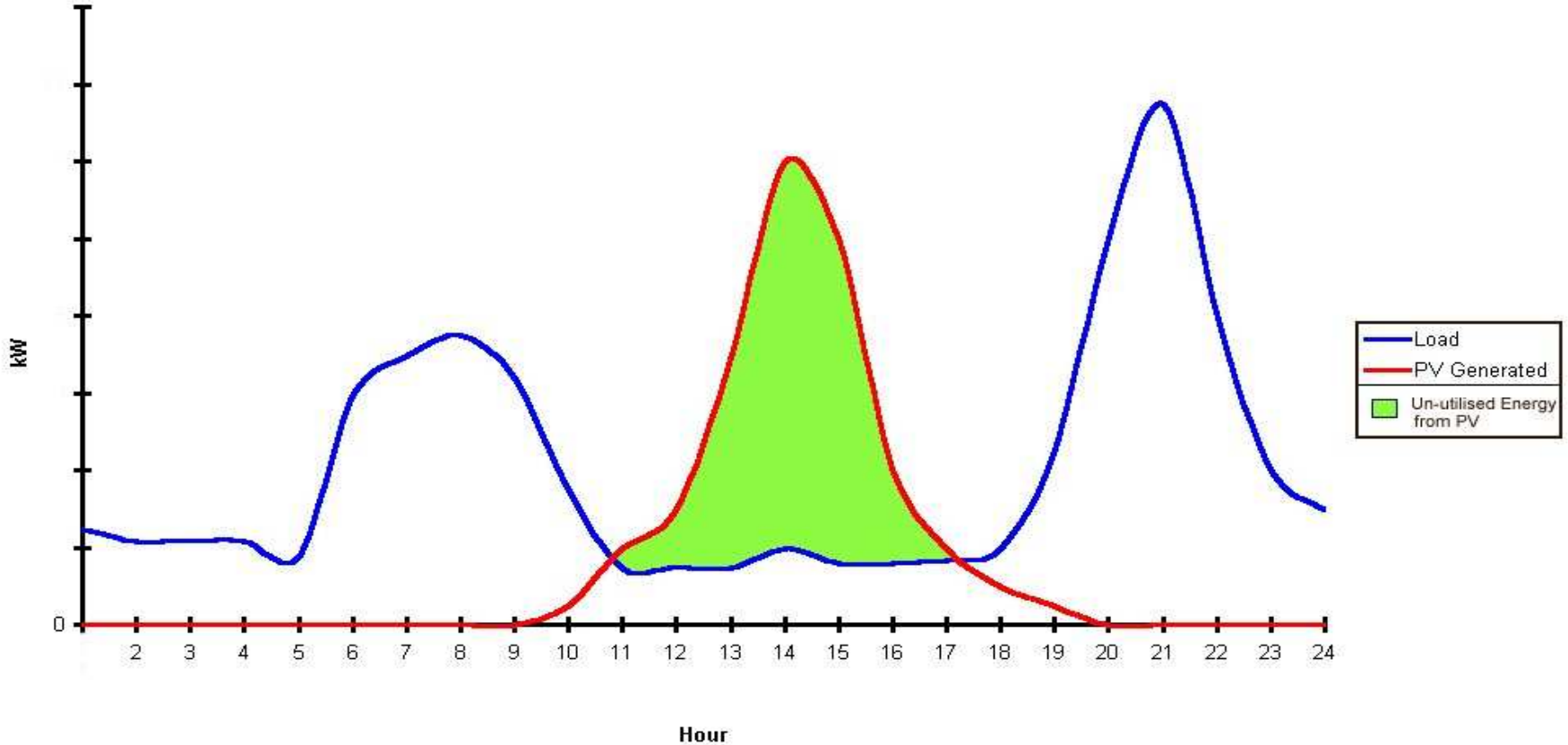
Distributed

Centralised vs Residential



Electricity profile

Residential Profile : Solar PV vs Electrical Loads



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What are the components?

1. Solar Modules
2. Inverters
3. Balance of Systems

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Utility Concerns Over Grid-connect

- **Main Concern**: Feeding power onto grid when grid has failed: Islanding
- Causing harmonics on the grid: affecting other customers and appliances

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Part 1

PV Array

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Role of PV Array

- Convert the power from the sun into DC electrical power

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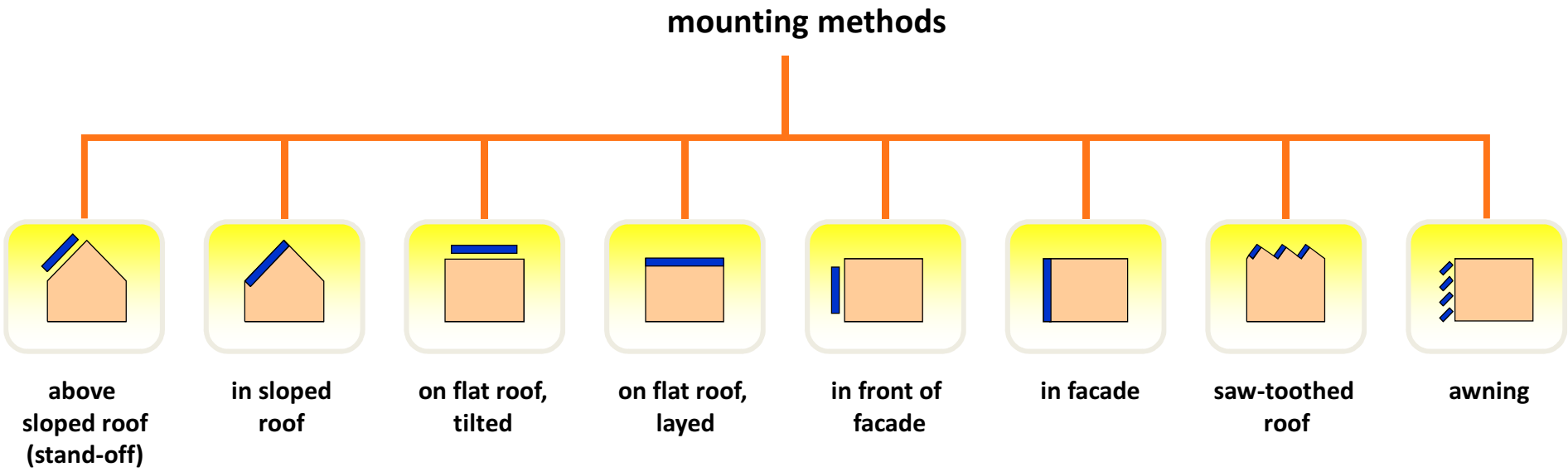
Size of Array

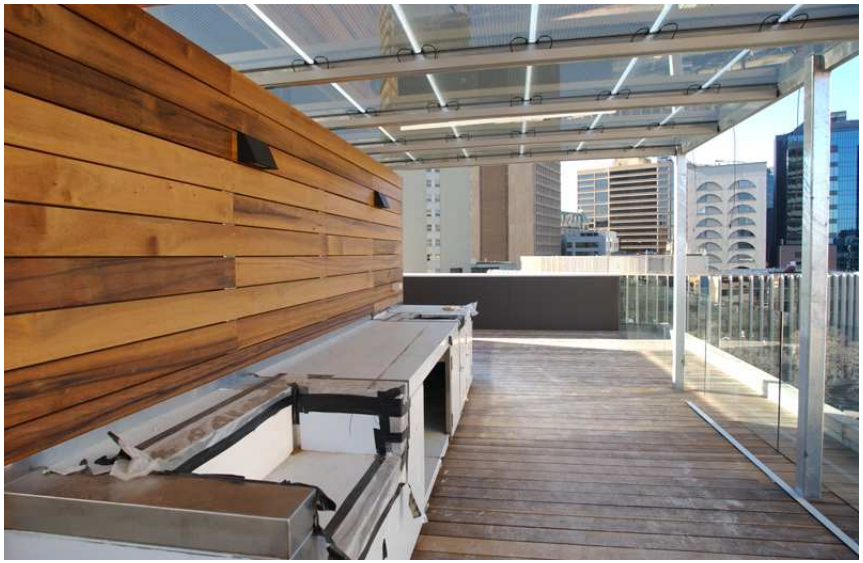
- For grid connect PV array can be as little as Qty 2 60 watt modules (100 Watt inverters) up to MW level.
- DC Voltage of Array and the configuration of the array is dependent on the type of inverter

Mounting Options



Arrays

- When included in the building they are called Building Integrated PV



Source: Szencorp (www.ourgreenoffice.com)

Part 2

Inverters

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What is a Grid Interactive Inverter?

- Inverts the DC power from PV Modules, to AC power .
- Synchronizes to the grid
- Feeds power onto the grid

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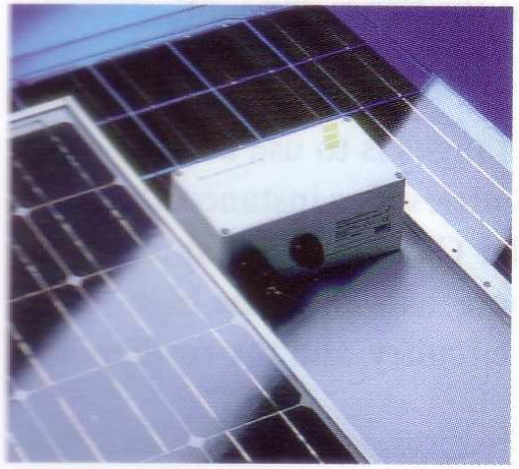
Types of Inverter

Central inverter: >20kW

String inverter: >1-10kW



Module inverter: <250W

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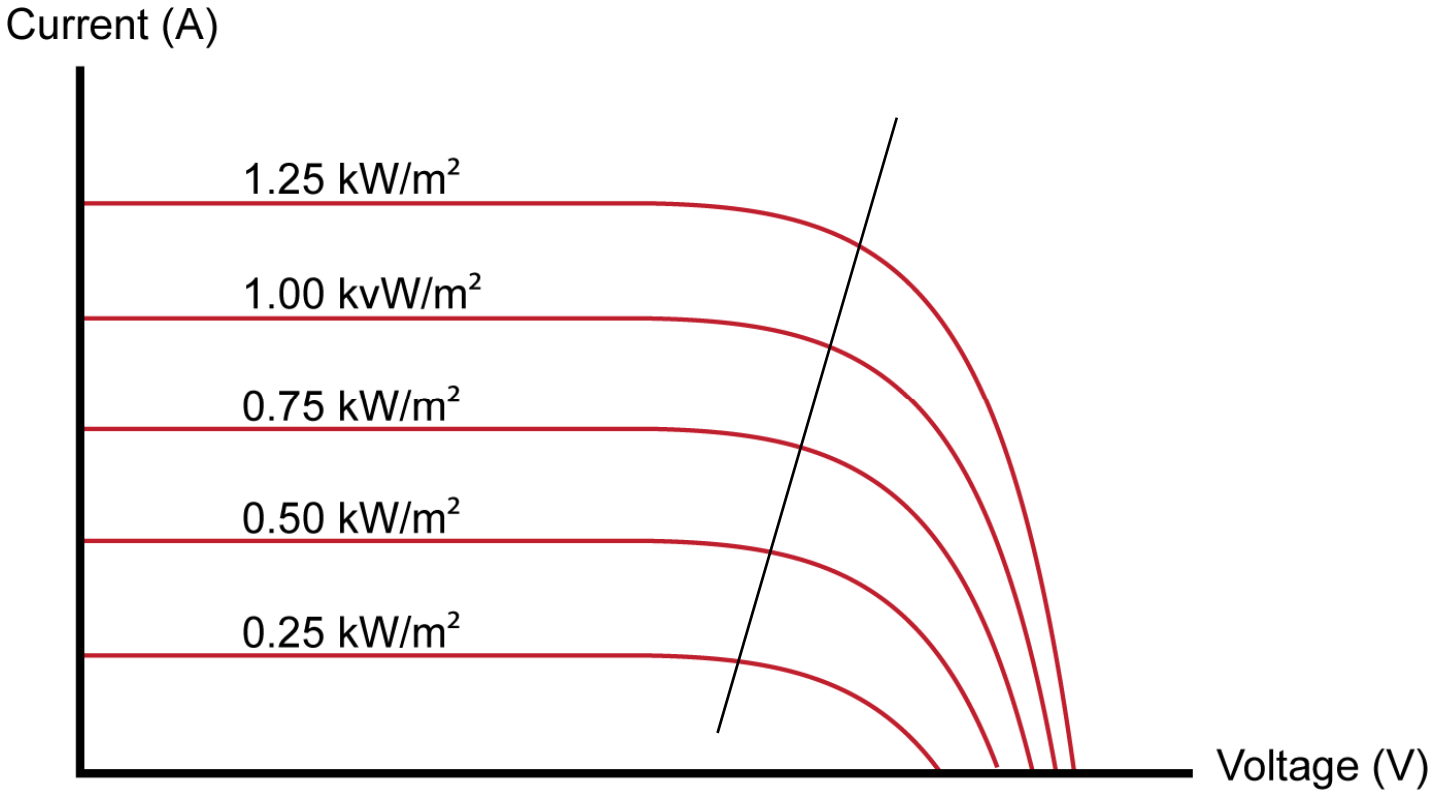
Common Features of Grid Interactive Inverters

- Contain Maximum Power Point Tracking



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Common Features of Grid Interactive Inverters

- Will have internal protection devices which will ensure inverter disconnects from grid when grid has failed.
- Passive & active protection against islanding.

Protection within Inverter

- Over voltage.
- Under voltage
- Over Frequency
- Under Frequency
- Islanding Protection

USA

	Minimum	Maximum
Frequency	58Hz	**62Hz**
Voltage (120V Utility Supply)	**105.6V**	**132V**

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USA Voltage Trip Settings

Voltage at Connection Point	Maximum Trip Time
V< 60 (V < 50%)	6 cycles
60 ≤V ≤ 105.6 (50% ≤V≤88%)	120 cycles
105.8 ≤V ≤ 132 (88% ≤V≤110%)	Normal Operation
132 <V < 165 (110% < V < 137%)	120 cycles
165 ≤V (137% ≤ V)	2 cycles

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Interconnection System Responses to abnormal Frequencies (USA)

Renewable Generator size	Frequency range (Hz)	Clearing Time (s)
≤ 30kW	>60.5	0.16
	< 59.3	0.16
>30kW	>60.5	0.16
	<59.8 to 57.0 (adjustable)	Adjustable 0.16 to 300
	<57	0.16

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Recommended Clearing Times for Frequency Variation (USA)

Frequency	Clearing time
> 62 Hz	0.16
58≤f≤62	Normal Operation
< 58 Hz	0.16

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What is Islanding?

- The grid has failed but there are enough PV systems on the grid that the inverters stay connected to the grid supplying the local loads
- This is a big concern for the utilities

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Types of Islanding Protection

- Frequency Drift
- Measuring impedance in the lines (Germany example)
- The Over and under Voltage and frequency protection is designed to help prevent islanding.
- When coming on - delay of 1min

Other Features of Grid Interactive Inverters

- LCD screens providing information such as:
  - kW or AC amps being produced.
  - DC amps feeding into inverter
  - kWh produced that day
  - kWh since inverter connected to
  - DC Voltage

•Remote monitoring and/or data logging

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Typical DC Voltages for Grid Inverters

- Stand alone inverters are typically designed around the following DC battery banks
  - 12V , 24V, 48V, 120V and 240V
- Grid connected inverters are designed around a large variety of string voltages and generally are rated for the number of modules in each string

Array Voltage issues?

- Strings of between 2 and 3 (nom 24V modules) produce dangerous DC voltage .
- Output rating based on Open circuit voltage.

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What Size Inverters are Typically Used?

- Small AC module inverters are cost effective up to about 600W. They also have the advantage in redundancy.
- Single households generally use only one inverter to suit system
- Large commercial systems can have one large inverter or use multiple inverters

Advantage of Multiple Inverters

- Redundancy
- Reduces the DC input current on any one cable.

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Energy Australia's Singleton Project

400kW Array

- One 200kW section has

  Qty 50 4 kVA Inverters

- The other 200kW section

  has Qty 4 50kVA Inverters

The Singleton photovoltaic solar array

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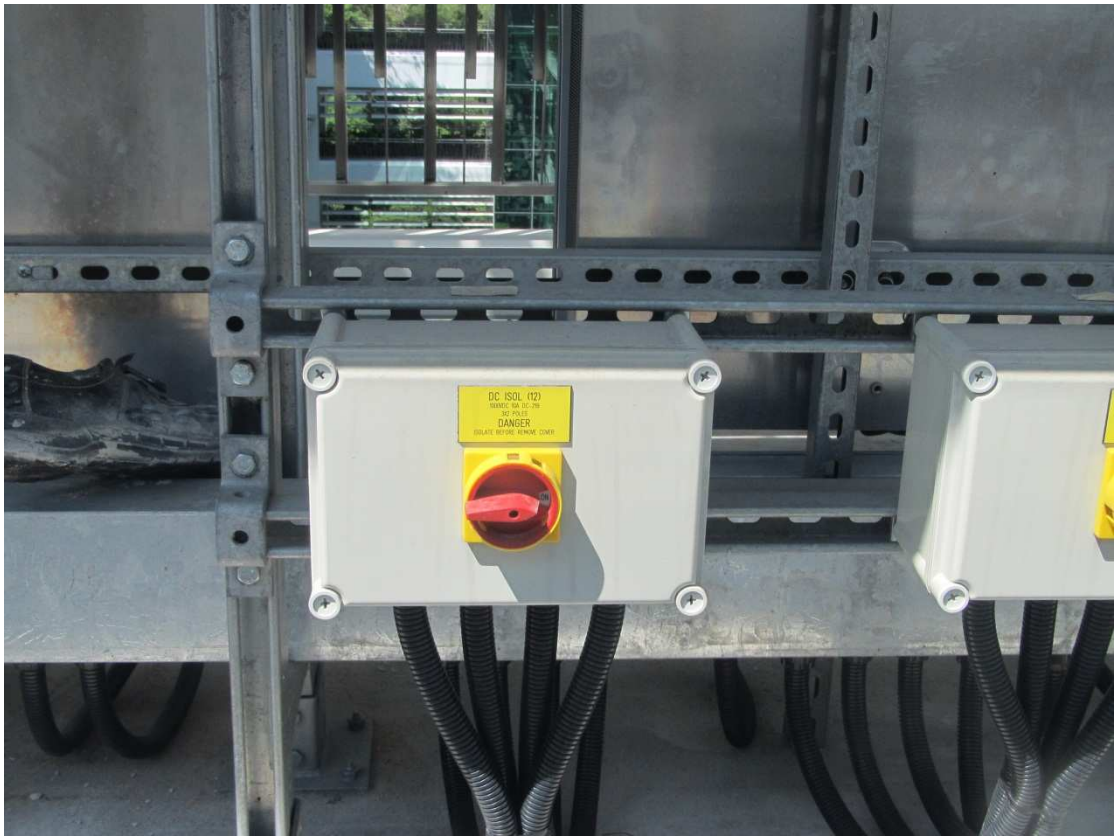
Balance of System

DC Solar
Isolating Switch



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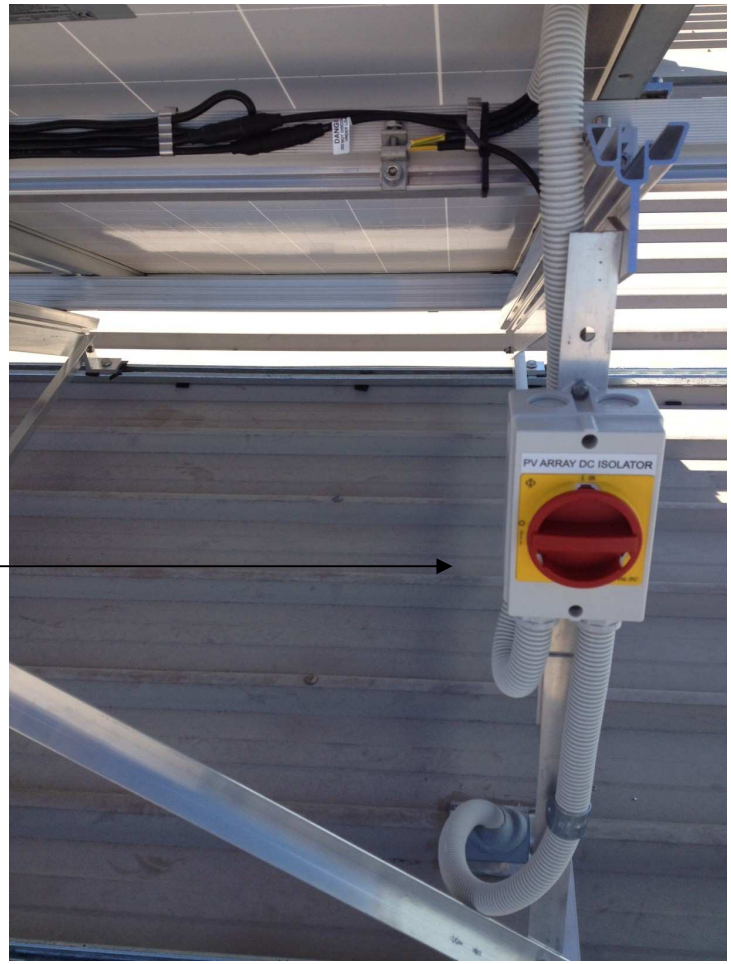
Balance of system II

DC Solar Isolating
Switch On Roof



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Balance of system III

AC Solar Isolating
Switch On Near Inverter

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AC Breakers used for DC

- Show video

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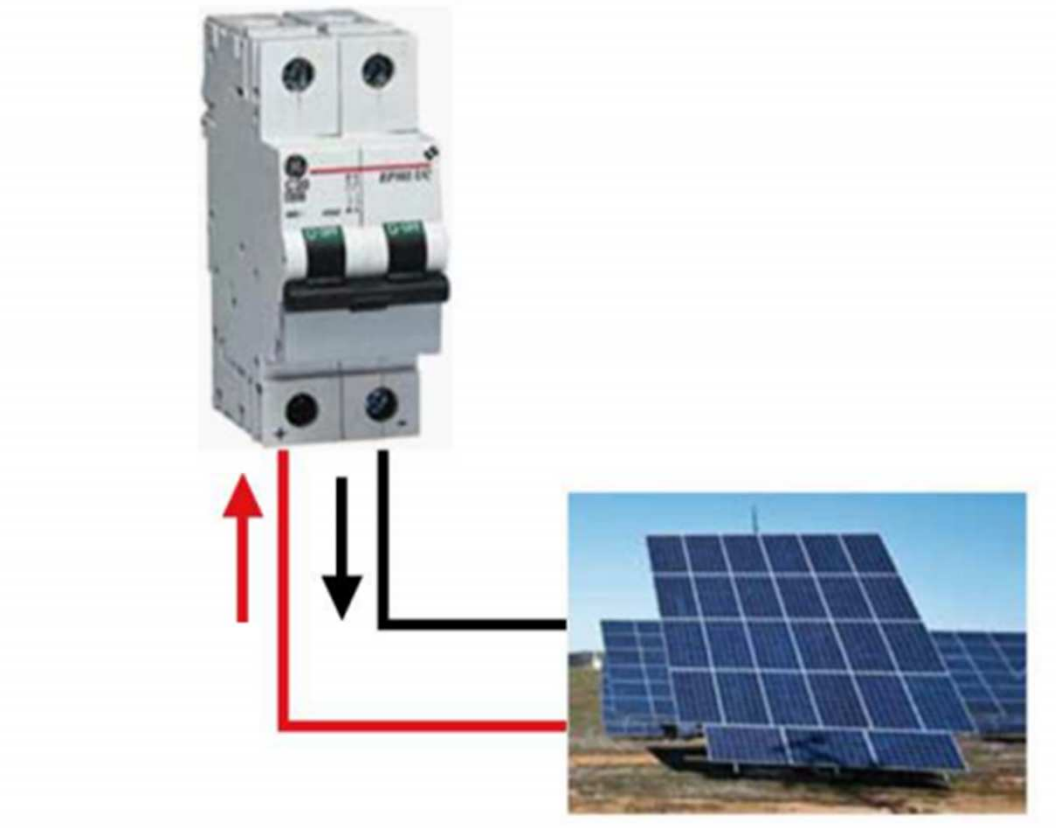
Isolation Devices

- Isolators on the DC side are only for load disconnection, though circuit breakers are often used
- Polarised isolators (circuit breakers) can be used, but if wired in reverse can be a fire hazard

Correct Circuit Breaker Wiring



Preferred connection of array to a Polarised Double Pole DC Circuit Breaker with markings on bottom of CB

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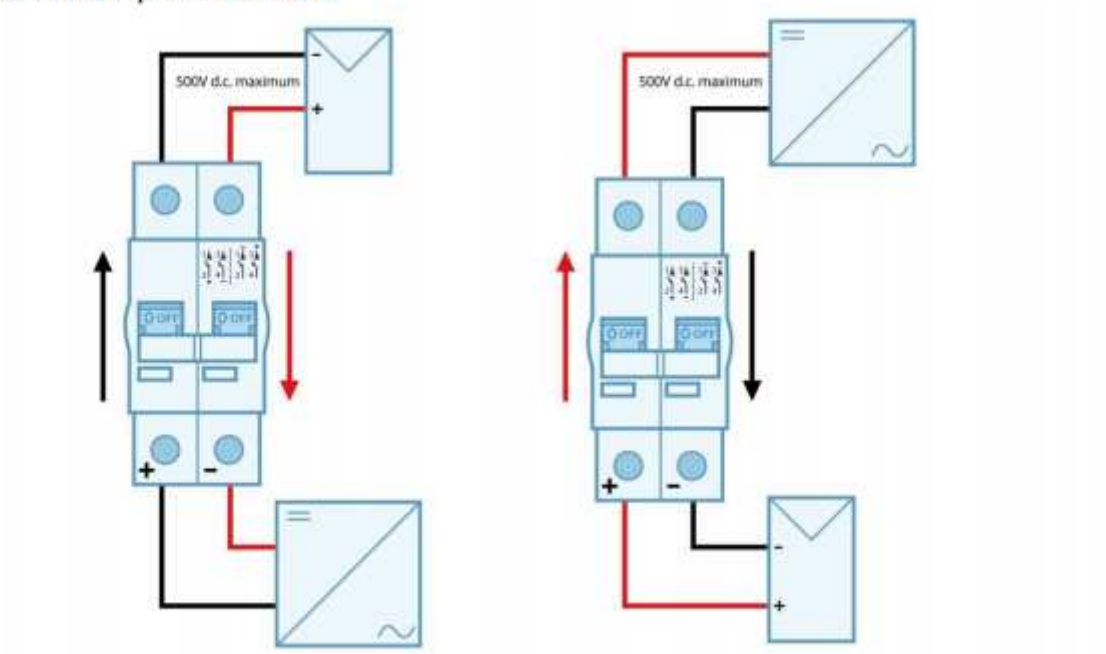
Correct Circuit Breaker Wiring

NOTE : For all connections, **the direction of the current flow is to be the same whether the array is connected to the top or the bottom.**



Two Ways of Connecting to a Polarised DC Breaker with markings only on bottom side.

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Double Marked Isolators

- Both terminals of each breaker are labelled positive or negative to indicate the required direction of current flow
- Positive and negative outputs of array connect to the respective breaker terminals

Double Marked Isolators

Polarised Breaker with markings at both ends of the breaker

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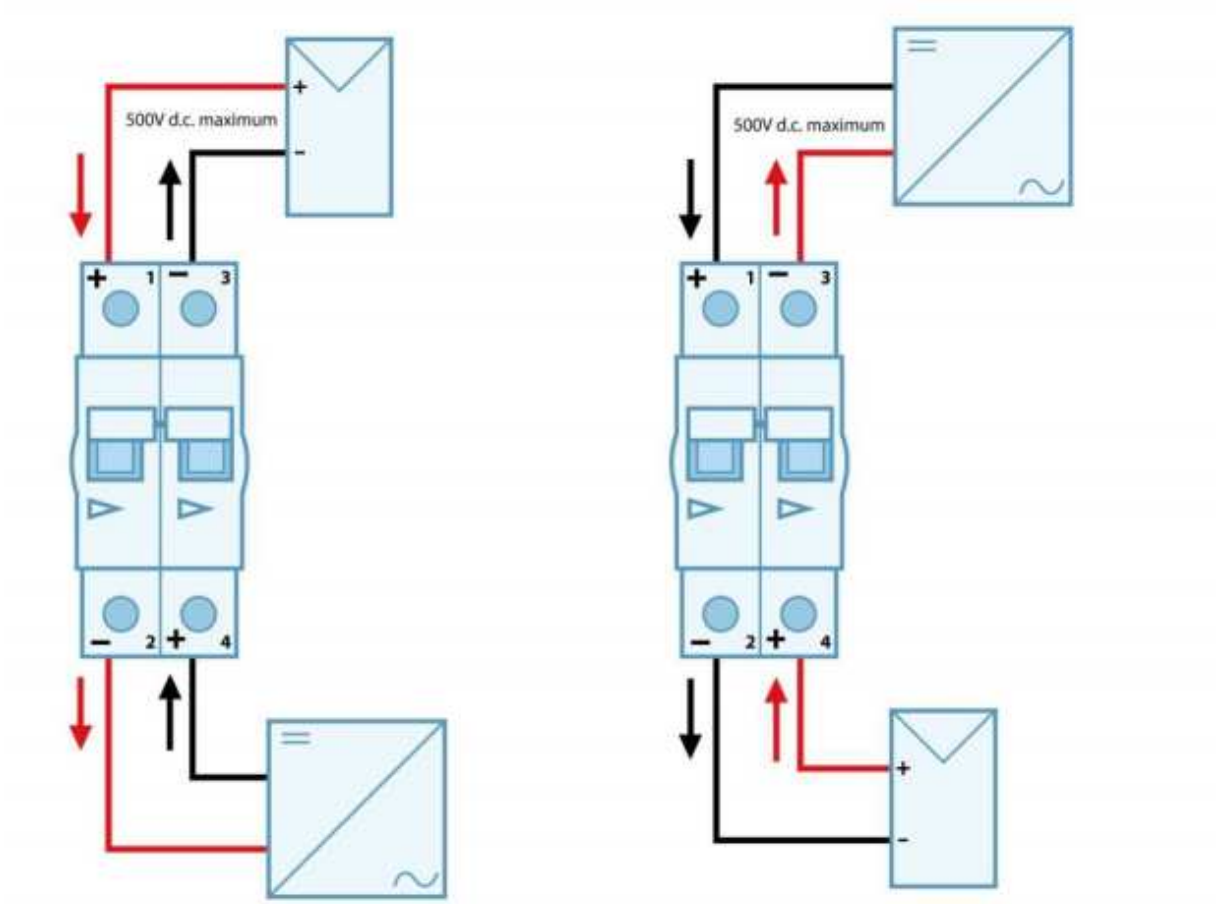
Double Marked Isolators



Two Ways of Connecting to a Polarised DC Breaker with markings on both sides of breaker.

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Non-polarised Isolators

- Non-polarised isolators operate safely breaking current flow in both directions through the device.
- There are no positive or negative terminals

Non-polarised Isolators

Non-Polarised Breaker

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AS/NZS5033

- Any DC solar cable within buildings must be in heavy duty conduit..
- NZ (and USA) require this as metal!!!
- Isolator beside the array.

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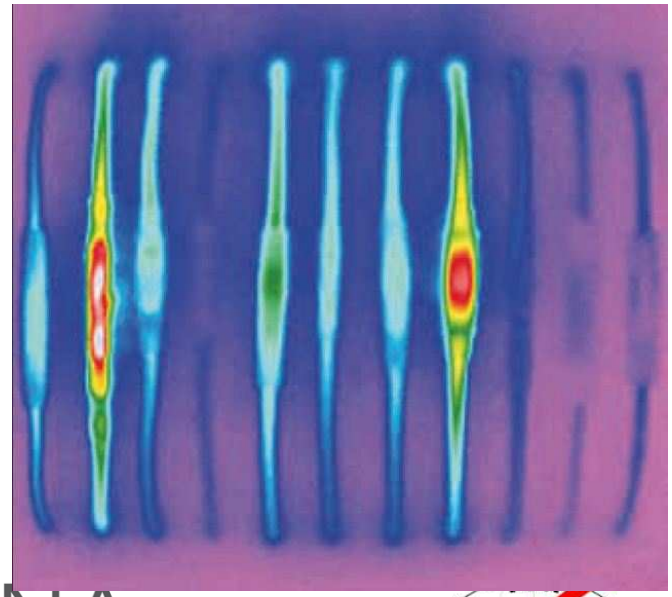
WIRING OF LV ARRAYS-Cont

- The installer shall ensure that all connectors used are waterproof and connected securely to avoid the possibility of a loose connection. Only connectors of the same type from the same manufacturer are allowed to be mated at a connection point.



- Show video

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DC ARCS

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VOLTAGE RISE

Cable Design

AC side can affect inverter voltage trip set points

- Voltage drop is also voltage rise depending of point of view

Multiple runs to consider

- From inverter to switchboard
- Switchboard to point of attachment
- Point of attachment to powerlines

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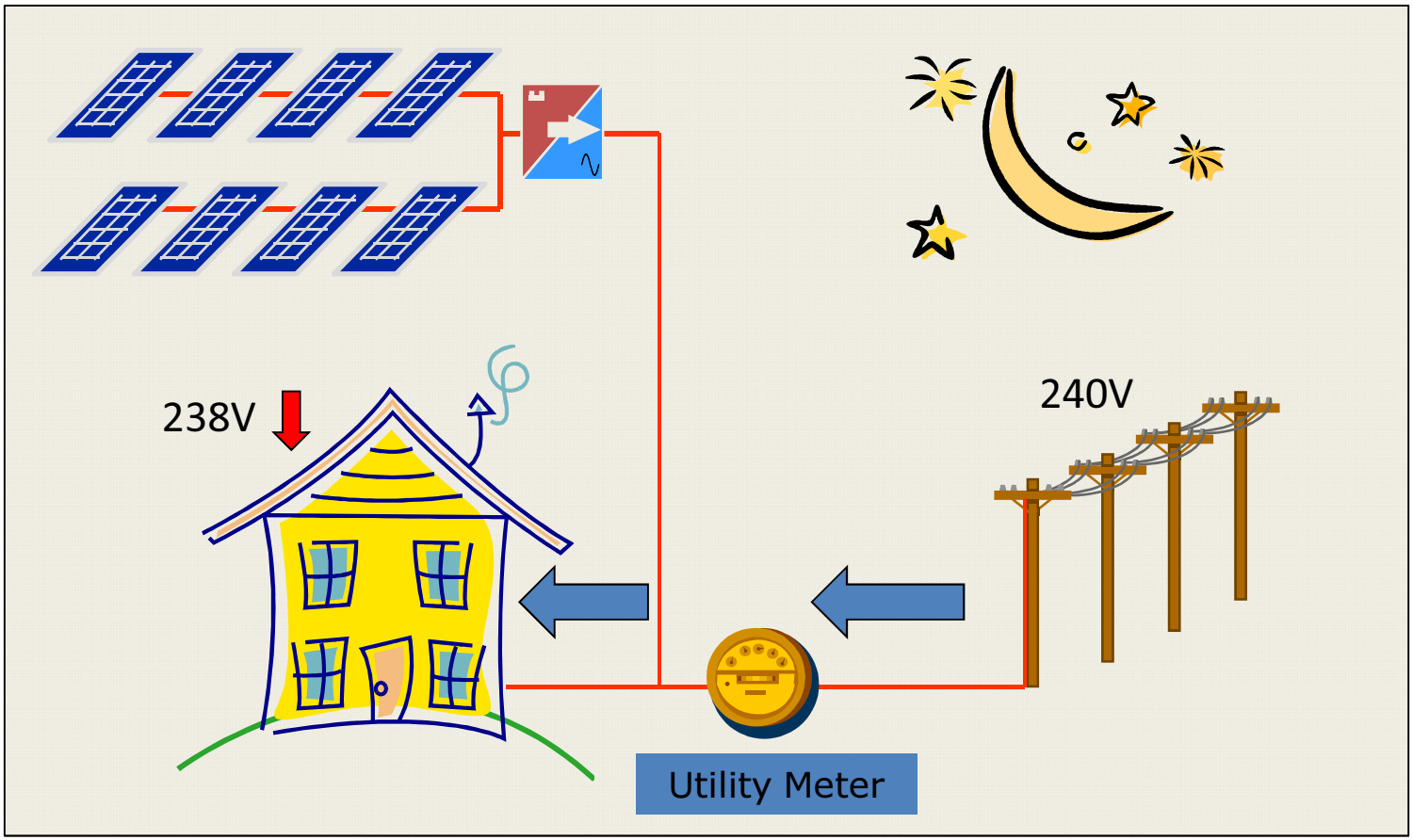
Night Time- 2kW Array



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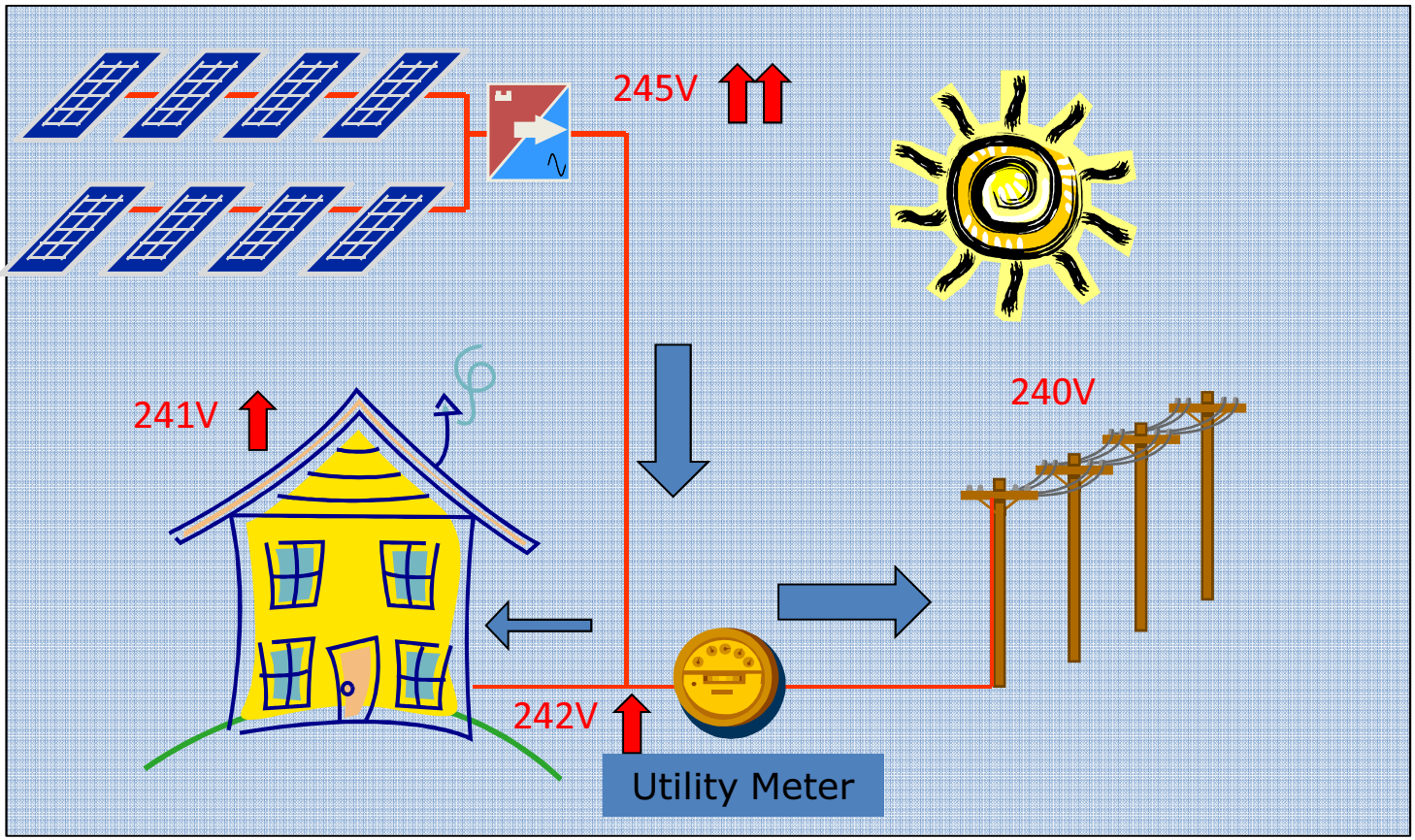
Day Time – 2 kW Array



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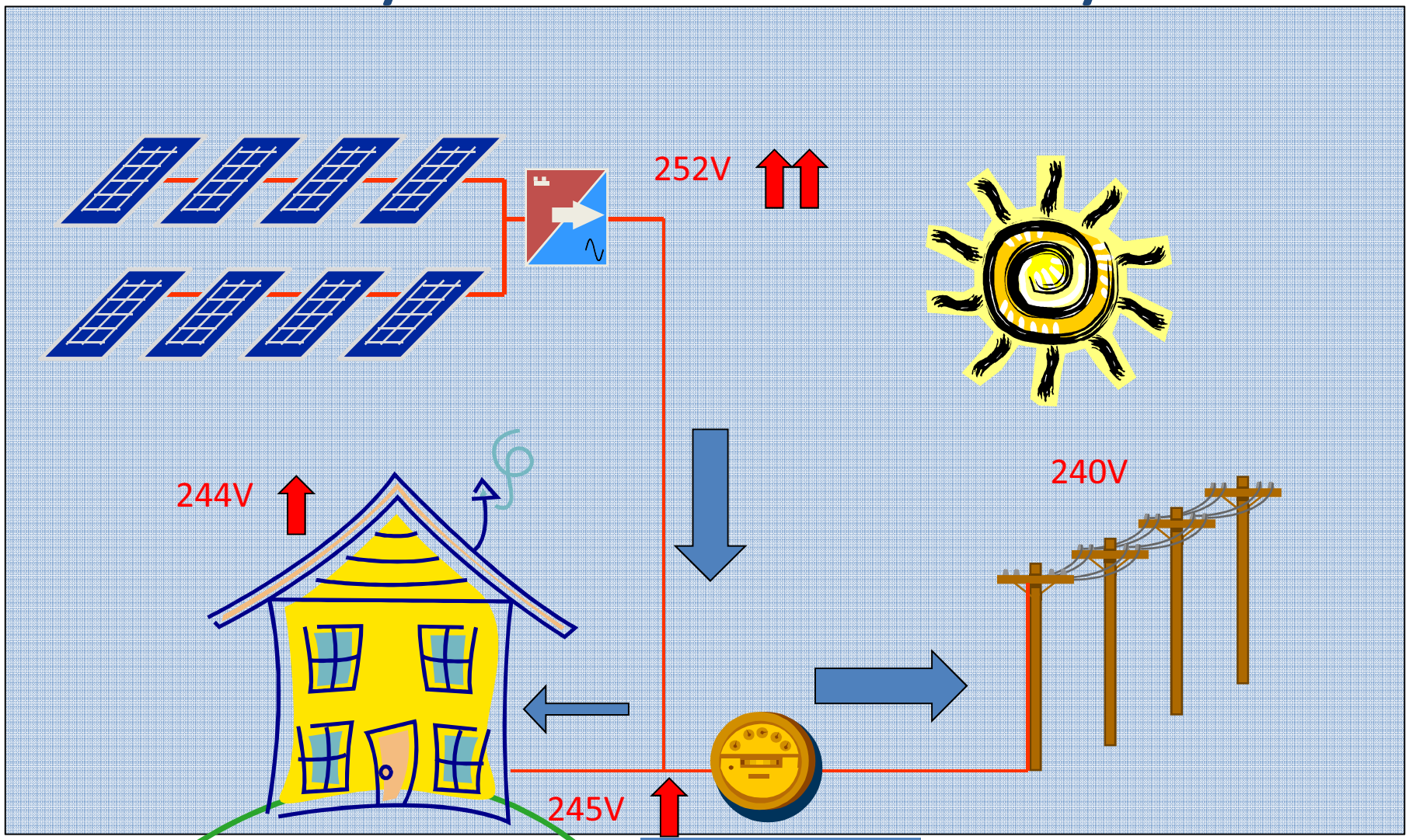
Volt Drop Summary

- Total AC drop is 2%
  - Not a huge problem for the set points
  - 2.5 mm^2 cable from inverter to switchboard
  - Approx 1.2 % drop to switchboard
  - Approx 0.8% drop to powerlines

Day Time – 5 kW Array



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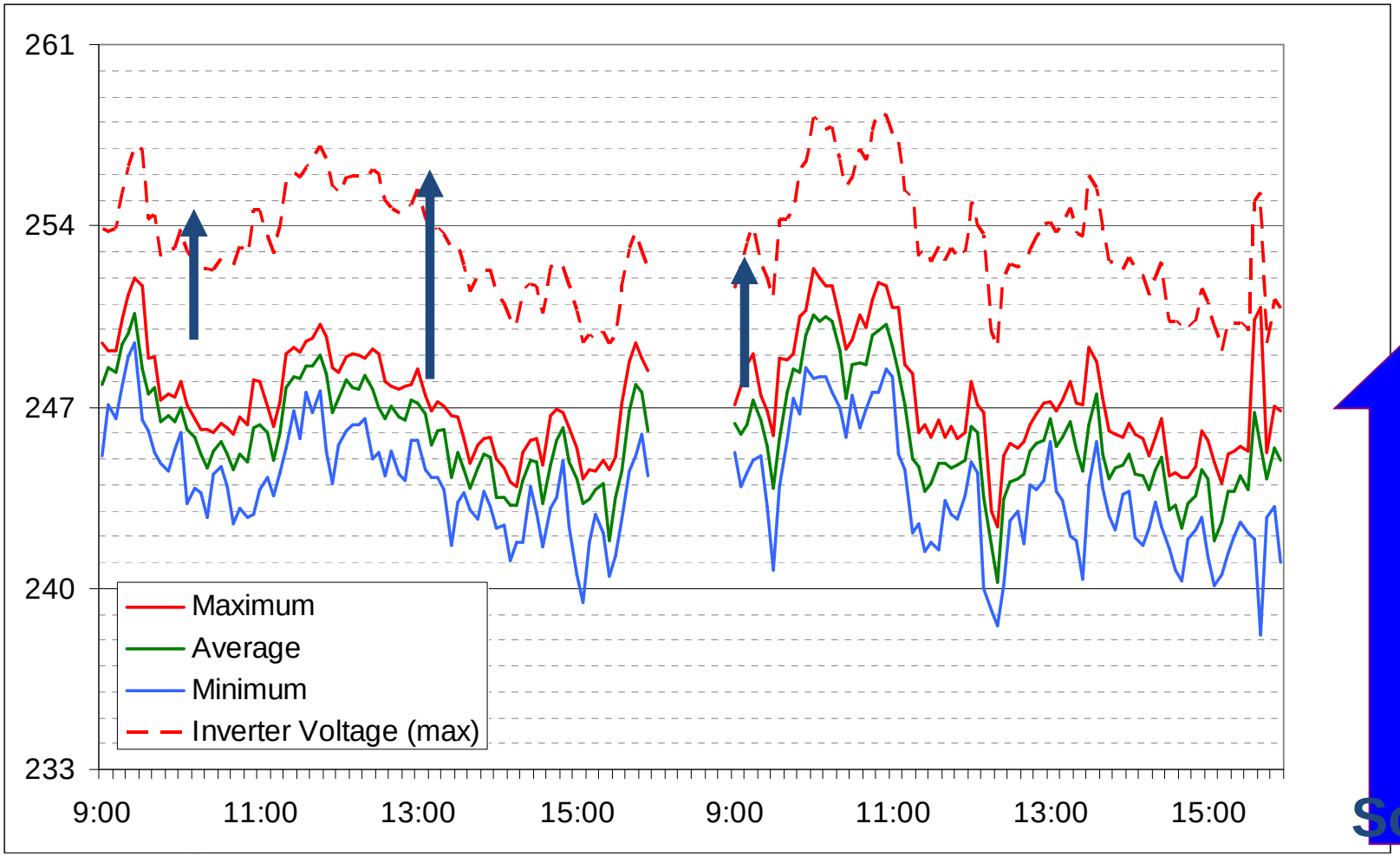
Volt Drop Summary

- Total AC volt drop is 5%
  - Approx 3 % drop to switchboard
    - This is also a 3 % power loss – revenue loss
  - Includes a further 2 % drop past switchboard to the power lines
  - The inverter operates at 12V above the grid voltage!
  - Not a huge problem for the set points
  - *Or is it?*

Grid voltage variability
(



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END OF PRESENTATION