Inspection and compliance checks for Solar PV Systems (AS/NZS / NEC)

Session 2B: Grid Tie or Grid-connect Inverters

Main Purpose of Inverters

- Convert d.c. power from the solar array to a.c power.
- The standard voltages are generally **240V or 230V a.c**. single phase or **415V** or **400V** 3 Phase with a frequency of **50 Hz** .
- US models typically come in 208/240V single phase, 480/277V three phase 60Hz frequency
- There are three categories of inverters in the market: grid-connect inverters, standalone inverters and multimode inverters. It is important to understand the difference between these inverter types.

Different Types of Inverters

- **Standard inverters used off-grid and for portable AC power**
  - Require batteries to provide the dc input, then provide AC output
  - Typically cannot parallel with other source of AC
- **Inverter/charger used off-grid**
  - Require batteries to provide the dc input, then provide AC output
  - Have AC input source used to charge batteries
- **Interactive Inverter/charger used off-grid**
  - Require batteries to provide the dc input, then provide AC output
  - Have AC input source used to charge batteries
  - Can parallel with other AC sources
- **Grid Connect inverters**

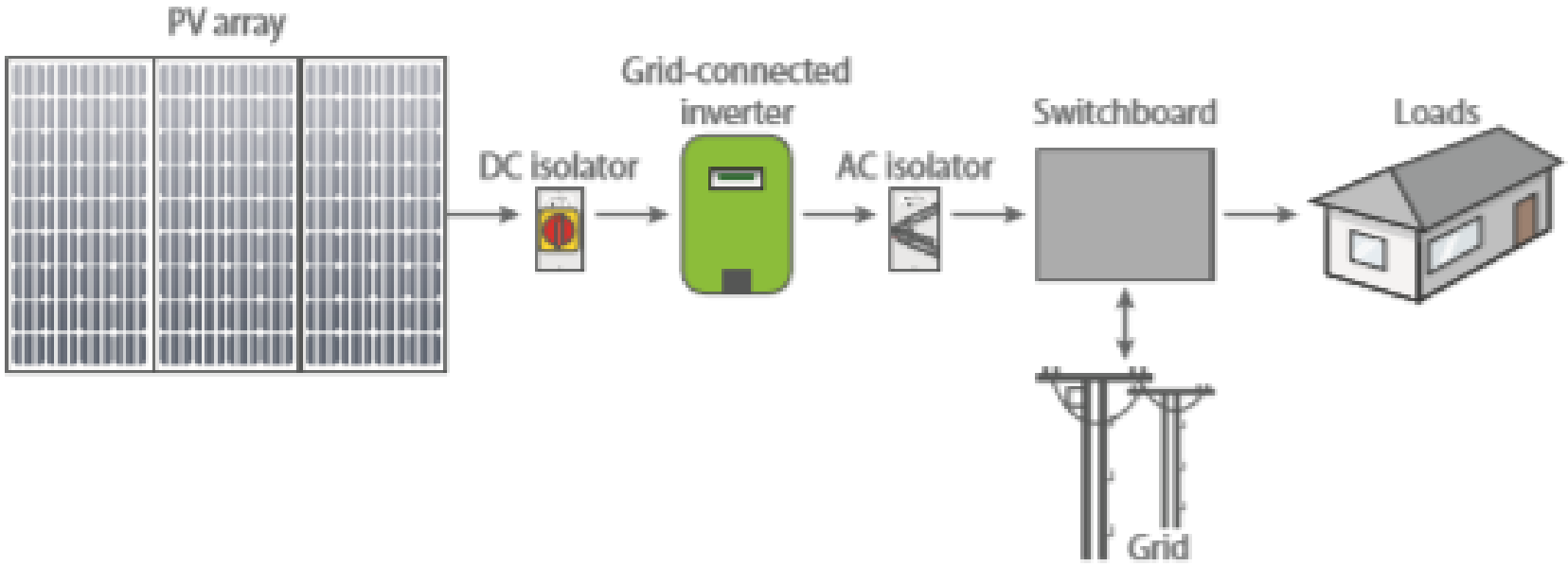
Grid-connect Inverters

- Also known as a grid-tied inverter.
- Is capable of producing an AC signal compatible with the grid.
- Must produce power within the acceptable voltage and frequency ranges specified by the relevant standards.
- Cannot independently produce an AC output: the inverter must be able to reference the grid to be able to connect to it. Without the grid reference, the inverter will not operate.

Grid-connect Inverters

- Generally contain an MPPT that keeps the PV array at its MPP.
- Have a permissible DC voltage window within which the solar PV must be operating before the inverter is able to produce the necessary AC voltage output to match the grid.
- Require grid protection to ensure that the inverter will not be exporting power to the grid when there are abnormal grid conditions.
- The operating requirements mean that the inverter has active and passive protection, and must shut down in certain conditions.

Grid-connect Inverters



Inverter Terminology

Separated Inverter	Non-separated Inverter
Isolated Inverter	**Non-isolated Inverter**
Galvanically Isolated Inverter	**Non-Galvanically Isolated Inverter**
Transformer Inverter	**Transformerless Inverter**
	

Inverter Specifications

- Inverters have numerous specifications relating to their electrical and physical properties.
- Determine the characteristics of the PV array that can be connected to the inverter, the nature of the inverter's output, and any other design considerations, such as the proposed installation location.
- The design specifications generally are divided into:
  - DC specifications
  - AC specifications
  - Efficiency
  - Physical specifications

Inverter Specifications

Technical Data	Sunny Boy 3000TL	Sunny Boy 3600TL
Input (DC)		
Max. DC power (at cos φ = 1)	3200 W	3880 W
Max. input voltage	750 V	750 V
MPP voltage range / rated input voltage	175 V to 500 V / 400 V	175 V to 500 V / 400 V
Min. input voltage / initial input voltage	125 V / 150 V	125 V / 150 V
Max. input current input A / input B	15 A / 15 A	15 A / 15 A
Max. input current per string input A / input B	15 A / 15 A	15 A / 15 A
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2	2 / A:2; B:2
Output (AC)		
Rated power (at 230 V, 50 Hz)	3000 W	3680 W
Max. AC apparent power	3000 VA	3680 VA
Nominal AC voltage / range	220 V, 230 V, 240 V / 180 V to 280 V	220 V, 230 V, 240 V / 180 V to 280 V
AC power frequency / range	50 Hz, 60 Hz / −5 Hz to +5 Hz	50 Hz, 60 Hz / −5 Hz to +5 Hz
Rated power frequency / rated grid voltage	50 Hz / 230 V	50 Hz / 230 V
Max. output current	16 A	16 A
Power factor at rated power	1	1
Adjustable displacement power factor	0.8 lagging to 0.8 leading	0.8 lagging to 0.8 leading
Feed-in phases / connection phases	1 / 1	1 / 1
Efficiency		
Max. efficiency / European Efficiency	97 % / 96 %	97 % / 96,4 %
Protective Devices		
Input-side disconnection point	•	•
Ground fault monitoring / grid monitoring	• / •	• / •
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	• / • / –	• / • / –
All-pole sensitive residual-current monitoring unit	•	•
Protection class (according to IEC 62103) / overvoltage category (according to IEC 60664-1)	I / III	I / III
General Data		
Dimensions (W / H / D)	490 / 519 / 185 mm (19.3 / 20.4 / 7.3 inch)	
Weight	26 kg (57.3 lb)	
Operating temperature range	−25 °C to +60 °C (−13 °F to +140 °F)	
Noise emission (typical)	25 dB(A)	25 dB(A)
Self-consumption (at night)	1 W	1 W
Topology	Transformerless	Transformerless
Cooling method	Convection	Convection
Degree of protection (according to IEC 60529)	IP65	IP65
Climatic category (according to IEC 60721-3-4)	4K4H	4K4H
Maximum permissible value for relative humidity (non-condensing)	100%	100%

DC Specifications

- The DC specifications of an inverter that should be considered include:
  - maximum DC power input
  - maximum input voltage
  - maximum power point tracker (MPPT) voltage range
  - number of inputs and MPPTs
  - maximum current per MPPT input.

Matching Power

Maximum size of Array

Technical data	Sunny Boy 3.0	Sunny Boy 3.6	Sunny Boy 4.0	Sunny Boy 5.0
Input (DC)				
Max. generator power	5500 Wp	5500 Wp	7500 Wp	7500 Wp
Max. input voltage	600 V			
MPP voltage range	110 V to 500 V	130 V to 500 V	140 V to 500 V	175 V to 500 V
Rated input voltage	365 V			
Min. input voltage / initial input voltage	100 V / 125 V			
Max. input current input A / input B	15 A / 15 A			
Max. input current per string input A / input B	15 A / 15 A			
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2			
Output (AC)				
Rated power (at 230 V, 50 Hz)	3000 W	3680 W	4000 W	5000 W[1]
Max. apparent power AC	3000 VA	3680 VA	4000 VA	5000 VA[2]
Nominal AC voltage / range	220 V, 230 V, 240 V / 180 V to 280 V			
AC power frequency / range	50 Hz, 60 Hz / −5 Hz to +5 Hz			
Rated power frequency / rated grid voltage	50 Hz / 230 V			
Max. output current	16 A	16 A	22 A[2]	22 A[2]
Power factor at rated power	1			
Adjustable displacement power factor	0.8 overexcited to 0.8 underexcited			
Feed-in phases / connection phases	1 / 1			
Efficiency				
Max. efficiency / European Efficiency	97.0% / 96.4%	97.0% / 96.5%	97.0% / 96.5%	97.0% / 96.5%

Max ac output of Inverter

MATCHING ARRAY VOLTAGE TO THE INVERTER

The number of modules in a string, and hence the maximum and minimum voltages of the string, must be matched to the inverters:

- Maximum dc input voltage ; and
- Minimum Maximum Power Point Tracker (MPPT) operating voltage;.

NOT MIN INPUT VOLTAGE

Input (DC)				
Max. generator power	5500 Wp	5500 Wp	7500 Wp	7500 Wp
Max. input voltage	600 V			
MPP voltage range	110 V to 500 V	130 V to 500 V	140 V to 500 V	175 V to 500 V
Rated input voltage	365 V			
Min. input voltage / initial input voltage	100 V / 125 V			
Max. input current input A / input B	15 A / 15 A			
Max. input current per string input A / input B	15 A / 15 A			
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2			
Output (AC)				
Rated power (at 230 V, 50 Hz)	3000 W	3680 W	4000 W	5000 W[1)]

NOT MAX MPPT VOLTAGE

Example

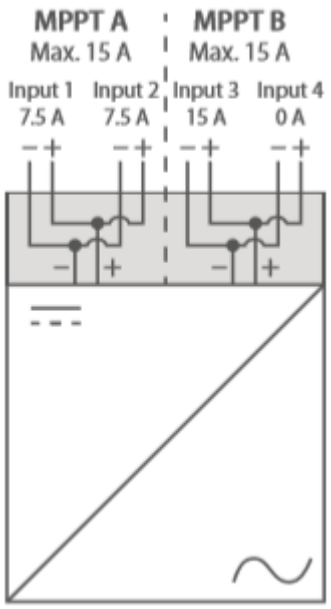
The SMA Sunny Boy specification sheet includes the following DC input information:

Max. input current input A / input B	15 A / 15 A
Max. input current per string input A / input B	15 A / 15 A
Number of independent MPP inputs / strings per MPP input	2 / A:2; B:2

- Number of independent MPP inputs = 2
- Strings per MPP input = A:2; B:2.

This data indicates that the inverter has two MPPTs, each of which has two inputs.

This means the inverter has a total of four PV inputs.



AC Specifications

Inverter specifications that need to be understood and considered in relation to the system design include:

- rated power output
- power factor
- output voltage and frequency
- harmonic distortion.

Grid-connect Inverter Protection Systems

Complications can arise when the grid experiences abnormal conditions

The inverter is disconnected from the grid when:

1. *The grid is interrupted (a blackout)*
2. *The grid operates over or under the permitted voltage and frequency thresholds.*

This protects the grid and prevents islanding.

Grid-connect inverters incorporate two types of grid protection:
1.Passive protection: inverter disconnects if it detects grid conditions that are over or under the voltage settings and/or over or under the frequency settings of the inverter

2.Active protection: inverter will cause its passive protection to operate if there is not a stable grid reference.

Anti-islanding

There are two main problems caused by PV systems when the grid experiences abnormal conditions or is interrupted:

1. **Islanding:** a distributed generator (e.g. a grid-connected PV system) continues to supply power to part of the grid after the utility power generator is no longer supplying power, creating an 'island'.
2. The exported power could pose a safety issue to utility workers working on the supply lines and cause further problems for the grid supply.
3. **Protecting the grid**: If islanding occurs, there is a danger that the power dispatched from the PV system will no longer be operating at the same voltage or frequency as the rest of the grid.
4. When grid supply is restored and the islanding ceases, these differences in voltage or frequency can damage the distribution wires, the inverter and equipment on the grid.

Inverter Protection Systems

Grid Interactive inverters will typically incorporate two types of protection:

- Self Protection if extreme operation conditions occur
- Protection to the grid- so that the inverter will disconnect supplying power to the grid in certain conditions- mainly objective when there is no power on grid (due to maintenance or fault)

The inverter will shutdown when it detects these shutdown conditions based on the protection settings.

Passive Protection

There are four forms of passive anti-islanding protection:

- Under-voltage protection (if under V_{min})
- Over-voltage protection (if over V_{max})
- Under-frequency protection (if under f_{min})
- Over-frequency protection (if over f_{max})

Over/Under Protection Setting Limits

- Protection settings will be dependant on the local utility and conditions.
- Double check over/under protection setting limits with the local utility

	Minimum	Maximum
Frequency	48Hz	52Hz
Voltage (230V Utility Supply)	200-210V	260-270V

This is and example of over/under protection setting limits from AS/NZS4777.2

Active Protection

- Active protection (also known as active anti-islanding protection) forces the passive protection of the inverter to operate under certain situations.
- The inverter will allow the detected abnormality to ‘drift’ so that the inverter shuts down under its prescribed passive protection parameters.

Self Protection Systems

Inverters have protections in place to prevent physical damage.

These include:

- Reverse Polarity Protection
- Protection against high temperature
- Protection against high d.c. voltages