

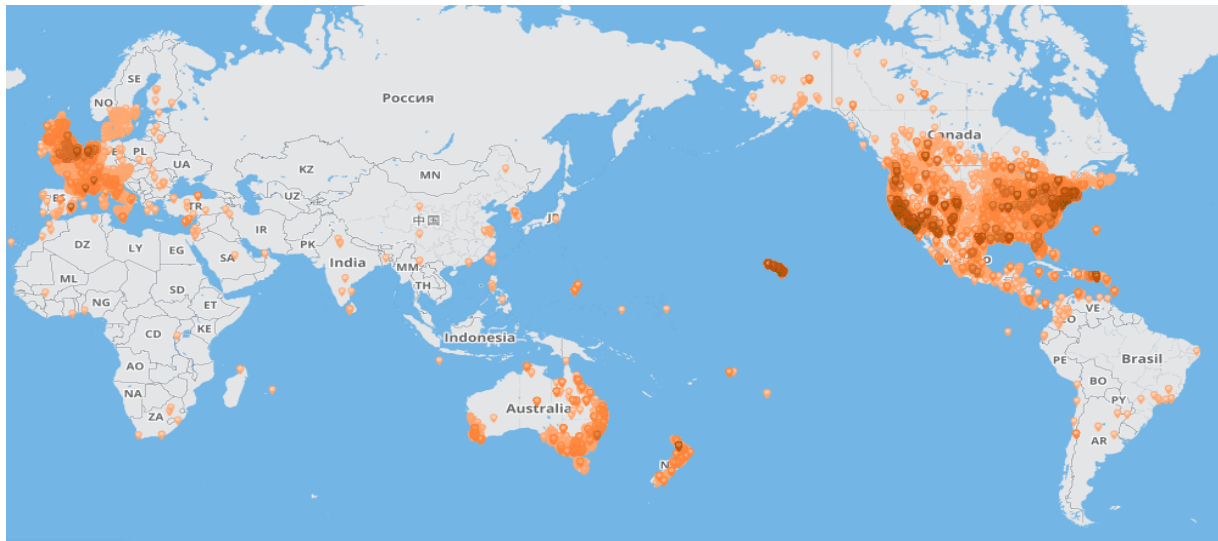
Enabling scale of Distributed Energy Resources (DERs): The need for an adaptive grid

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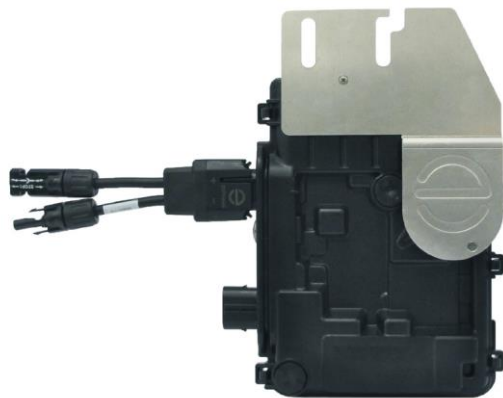
Global Footprint

Smart Solar Systems



- 15 Million Microinverters
- 580,000 Systems
- 100 Countries
- 3TB Data/day

Designed in Christchurch for the World



What enables an adaptive grid?



NOT



NOT

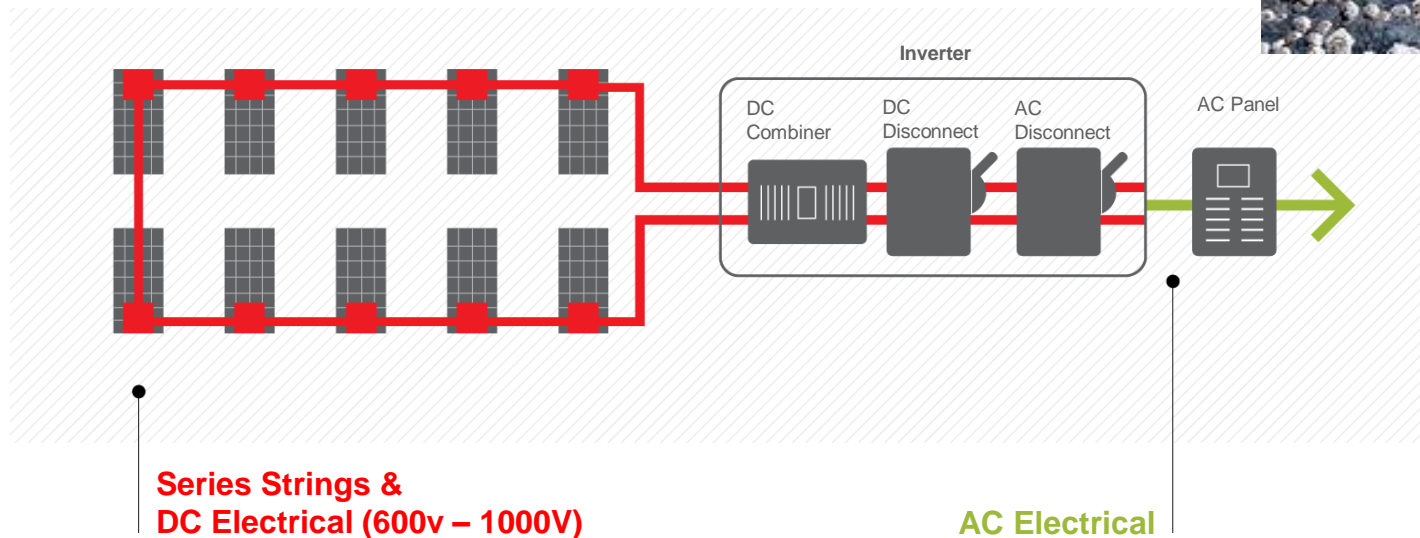


Smart Energy

- The operating environment is evolving
 - Grid
 - Load
 - Weather
 - Tariffs
- Distributed Energy Resources (DERs) need to be **Integrated** into, not attached to the grid – Cloud connected and managed
- DERs will have to **Adapt** over time – Software defined systems

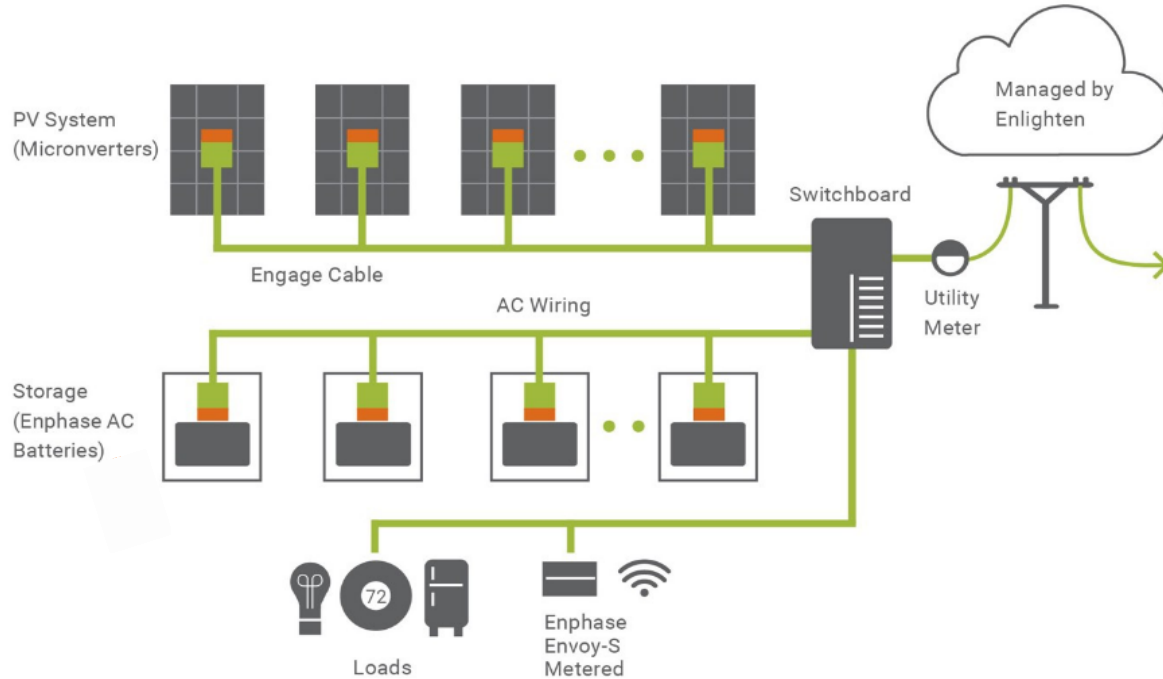
Traditional String Inverter System

Dumb Solar



Enphase Home Energy System

Smart Solar and storage



Technology Innovation



Advanced Semiconductor Design

Enphase Microinverter

- Converts DC to AC



Proprietary Networking Technology

Envoy Communications Gateway

- Collects performance information



SaaS Energy Management Platform

Enlighten Platform

- Analytics ensures maximum production

Proprietary technology
128 PATENT FAMILIES

Sat, May 13, 2017

10°C Partly Cloudy

**19.3** kilowatt-hours
produced

Approximately 6.5 kWh exported to grid

**28.7** kilowatt-hours
consumed

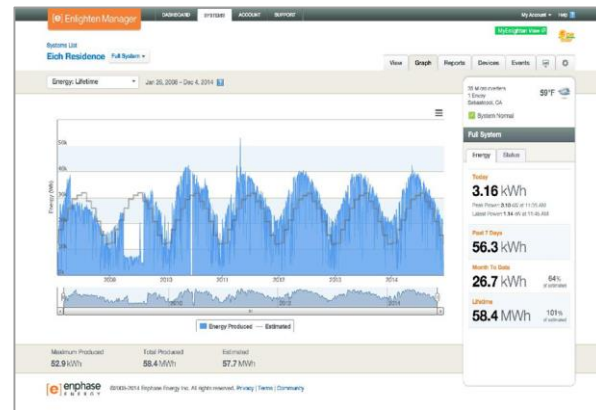
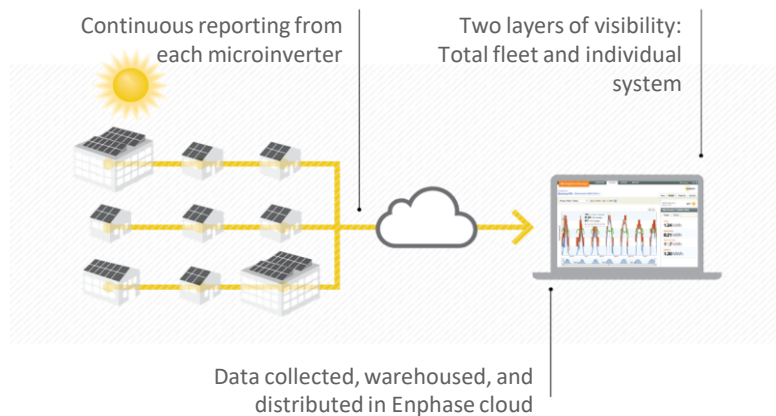
Approximately 16 kWh imported from grid

**9.50** kilowatt-hours
net energy imported

May 13, 2017 2:30 - 2:45 PM

**689** watt-hours
from solar**226** watt-hours
from grid**119** watt-hours
from storage

Enlighten: Powerful Data for All Stakeholders



Solar Installers

- Performance monitoring
- Customer service management
- Remote diagnosis and repair

System Owners

- Performance
- Educational information
- Personal connection to PV system

Utilities

- Remote adjustment of grid protection behaviour
- Power production
- Grid status (voltage, current, waveform)

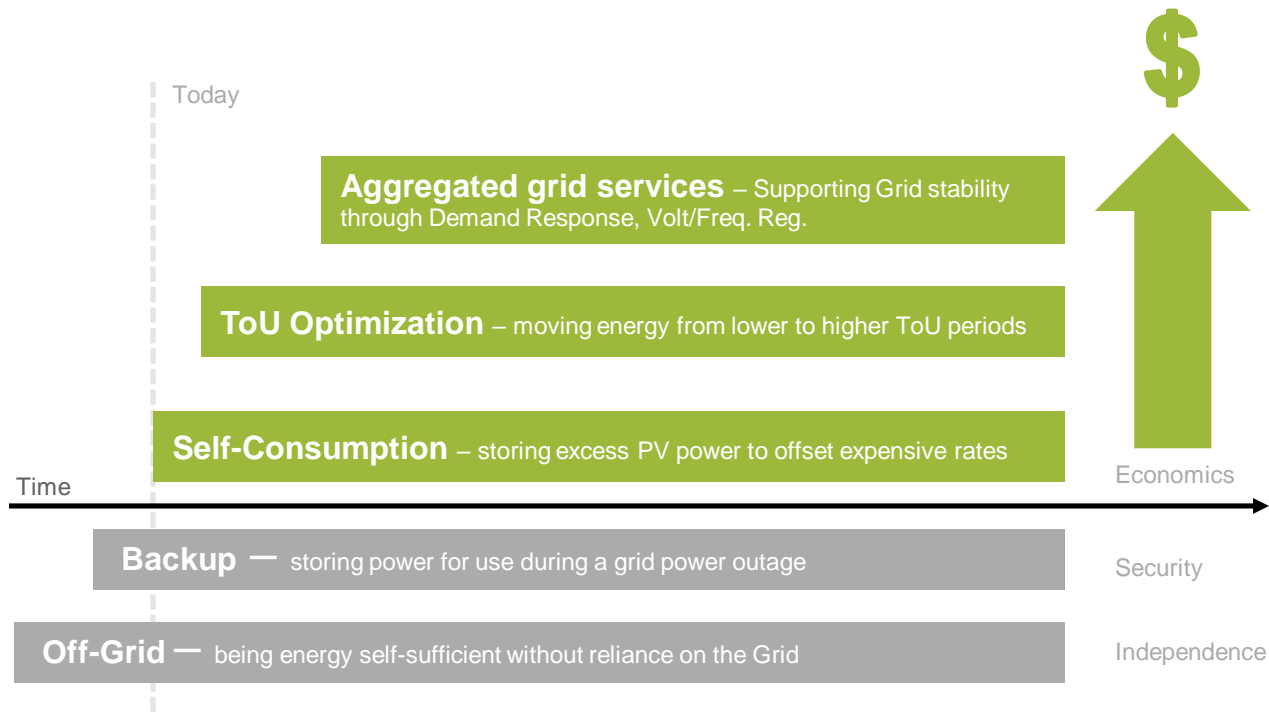
The Hawaii Story....

- Explosive growth
 - ~15% penetration
- Solar “attached” to the grid
- Grid reliability issues
 - voltage and frequency fluctuations
- Processes, systems, diagnostics not equipped for the volume or decentralised / local nature of grid issues
- Slowdown and complete stop of interconnections

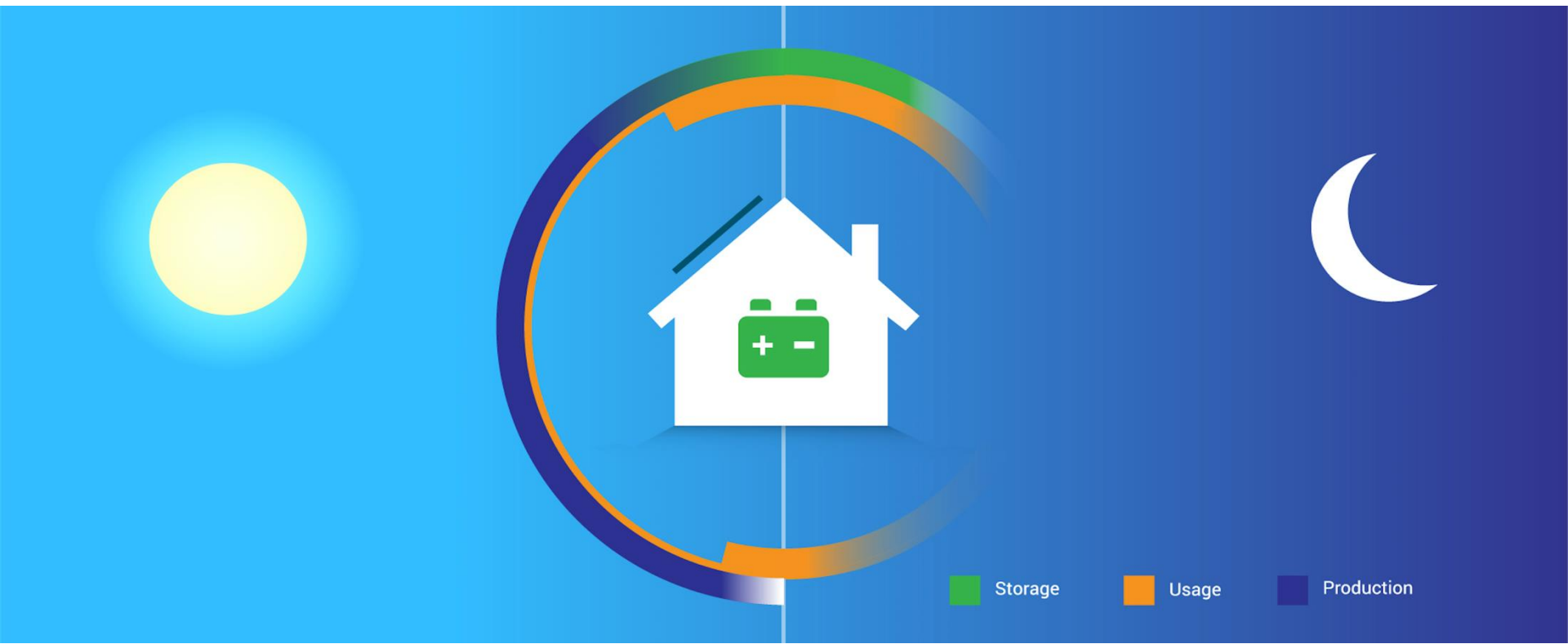


Scaling storage for the grid

Evolution of Use Cases for Storage

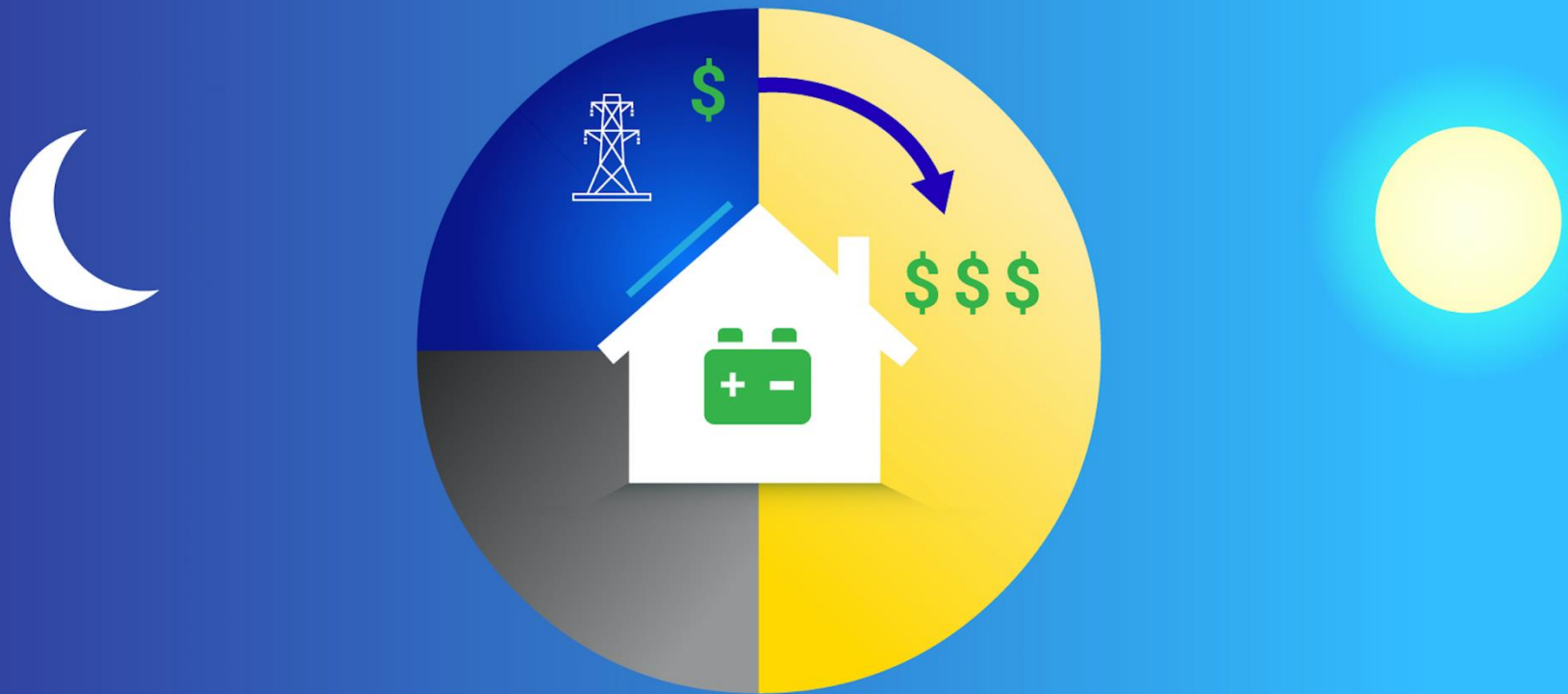


New use cases: **Self-consumption**



Store the excess solar production for later use.

New use cases: Time-of-use bill management



Draw energy from the grid or PV when prices are low and store it. Use it when prices are high.

Back-up vs. self-consumption

Back-up power

- Batteries should be fully charged and sit idle... waiting for grid outage
- Battery capacity should be oversized to account for poor solar resource
- Inverter(s) should be oversized to handle surges in loads
 - High internal temperatures from surging damages battery cells
- Best suited for power batteries

Self-consumption

- Batteries should be used as much as possible to maximize benefit
- Batteries should be right-sized to collect most excess solar generation
- Inverter(s) should be right-sized to match batteries charge/discharge rate
 - This preserves the health of the battery
- Best suited for energy batteries

There is no good single solution for both use cases!

Recommendations – Integrated DER Systems

Smart Energy

- Cloud connected and managed
- Software defined
- **Advanced Grid Functions**
 - Volt/VAR optimization
 - Ramp rate control
 - Curtailment
 - Frequency/Watt optimization
 - Fault ride through (V&F)
 - Capacity and VAR Demand Response

Follow guidelines set in CAR21 and 14H

What is different in AS/NZS 4777.2:2015?

Grid protection settings

- **Standard voltage/frequency settings nationwide**
 - Narrower window than 4777.3:2005
- **New parameter: two-step overvoltage protection (fast and slow limits)**
- **New parameter: 10-minute average overvoltage limit**

Parameter	4777.2:2005		4777.2:2015		
	Trip limit	Disconnection time	Trip limit	Trip delay time	Disconnection time
Undervoltage	200 – 230 V	2 s	180 V	1 s	2 s
Overvoltage 1	230 – 270 V	2 s	260 V	1 s	2 s
Overvoltage 2	—	—	265 V	—	0.2 s
Underfrequency	45 – 50 Hz	2 s	47 Hz (Australia) 45 Hz (New Zealand)	1 s	2 s
Overfrequency	50 – 55 Hz	2 s	52 Hz	—	0.2 s
10-min average Overvoltage	—	—	244 – 258 V 255 V (AU default) 248 V (NZ default)	—	3 s

What is different in AS/NZS 4777.2:2015?

- **DNSP control through Demand Response Modes**
 - Similar to demand response modes for air conditioners or hot water cylinders
 - Allows DNSP to curtail or increase power on command through a “Demand Response Enabling Device” (DRED)

DEMAND RESPONSE MODES (DRMs)	
Mode	Requirement
DRM 0	Operate the disconnection device
DRM 1	Do not consume power
DRM 2	Do not consume at more than 50% of rated power
DRM 3	Do not consume at more than 75% of rated power AND Source reactive power if capable
DRM 4	Increase power consumption (subject to constraints from other active DRMs)
DRM 5	Do not generate power
DRM 6	Do not generate at more than 50% of rated power
DRM 7	Do not generate at more than 75% of rated power AND Sink reactive power if capable
DRM 8	Increase power generation (subject to constraints from other active DRMs)

- **Zero Export and export limiting**
 - Allows the PV system to limit amount of power exported to the network.

What is different in AS/NZS 4777.2:2015?

Advanced Grid Functions

- **Autonomous, dynamic responses to grid conditions**
 - Frequency/Watt: power output adjusts based on frequency
 - Volt/Watt: power output adjusts based on voltage
 - Volt/VAr: power factor adjusts based on voltage
- **Allows for systems to stay connected during (and even help remedy) grid events**

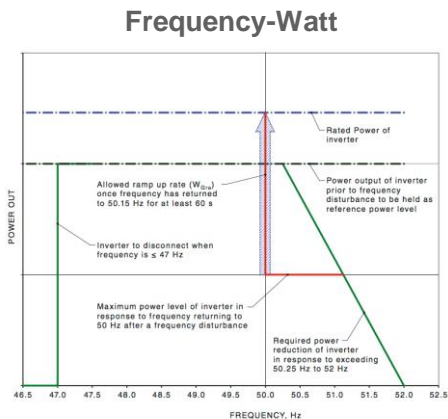


FIGURE 7(A) EXAMPLE FREQUENCY RESPONSE FOR OVER-FREQUENCY CONDITIONS FOR f_{nom} OF 50 Hz

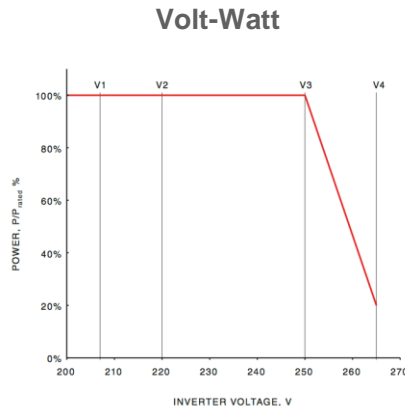


FIGURE 2(A) EXAMPLE CURVE FOR A VOLT-WATT RESPONSE MODE (AUSTRALIA)

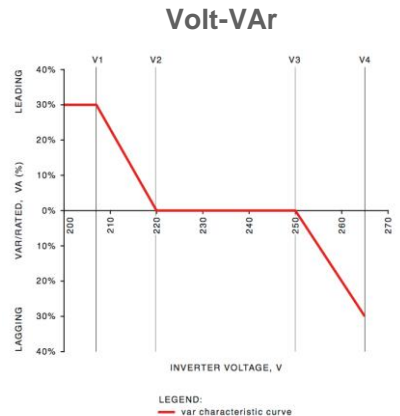


FIGURE 3 EXAMPLE CURVE FOR A POSSIBLE VOLT-VAr CONTROL MODE (AUSTRALIA)

Conclusion

- Learning from mistakes
- Smart Energy System is an integral part of the Smart Grid
- Adaptive, Controllable, Hyper-connected
- Support for Advanced Grid Functions (AGF)



Be the Brains and not the Barnacle

Thank you!