How to overcome problems of grid connectivity to Green Electricity?

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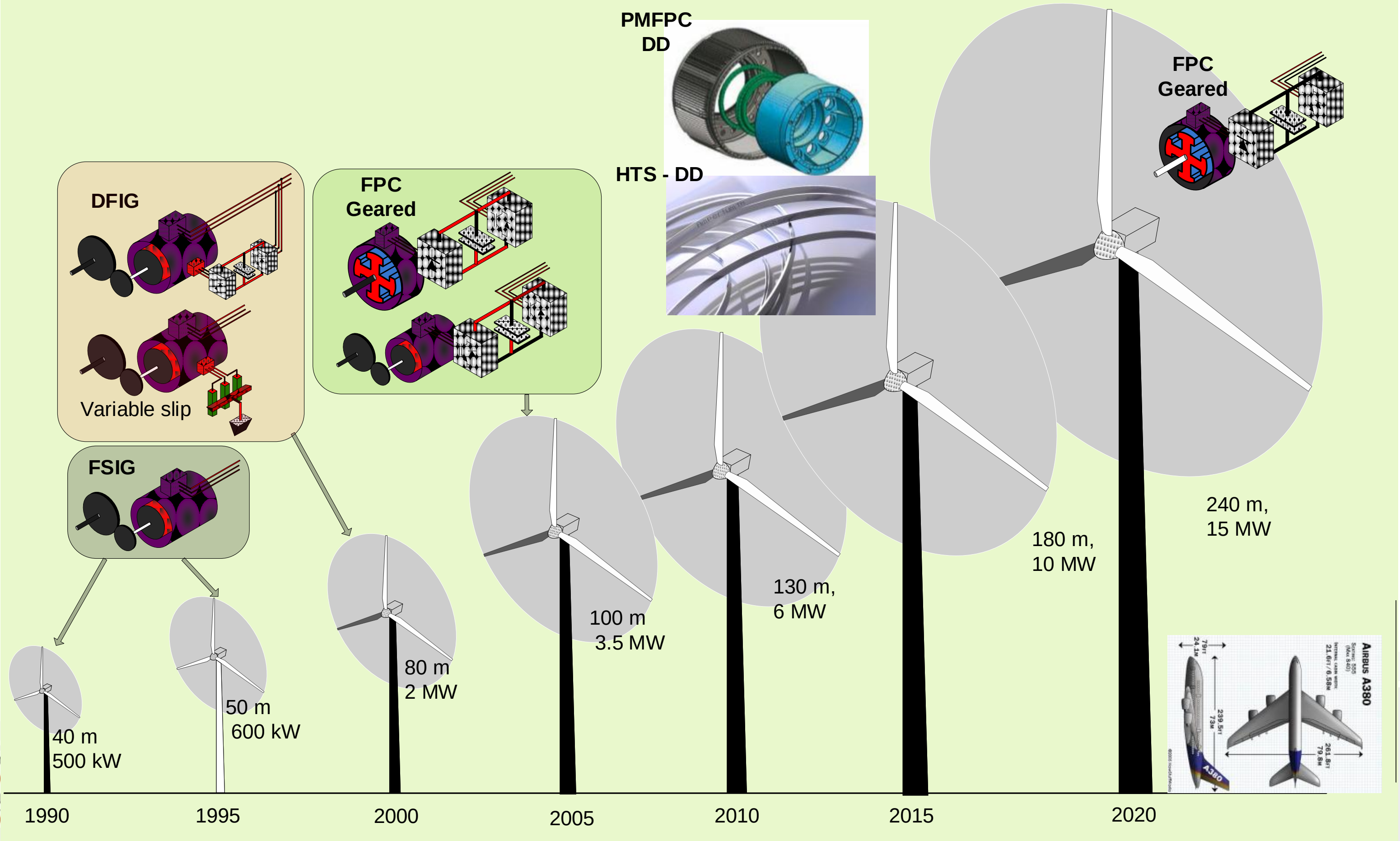
- Landscape today
- Connection issues and solutions
  - Network operational issues
  - Network limit issues
- Non-Technical Barriers for Renewable additions
- System-level solutions for Renewable Additions
- Considerations for Renewable additions

LANDSCAPE TODAY

Wind turbines



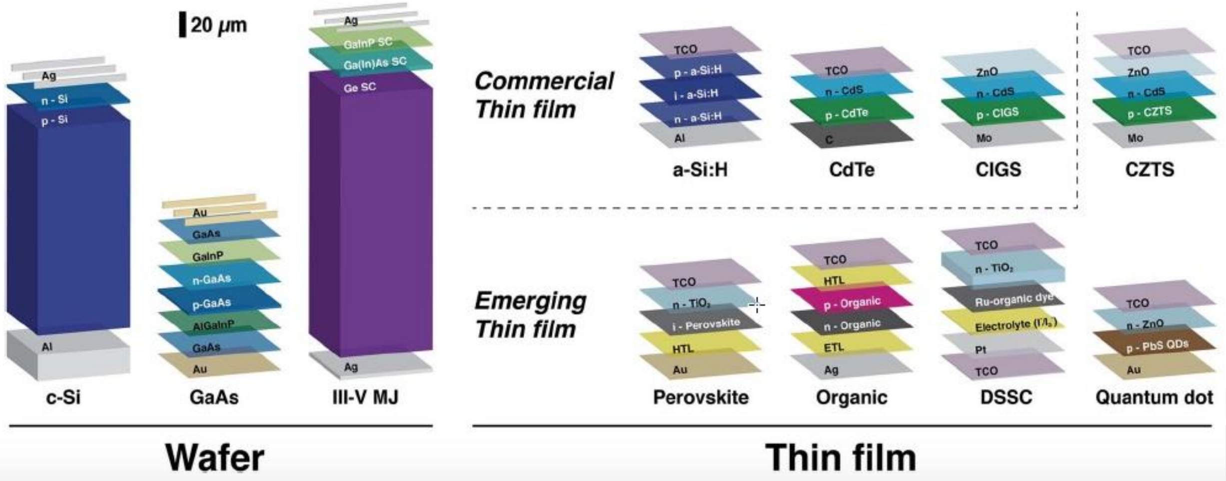
PV technologies

PV technologies

- Wafer-based
- Thin-film cells

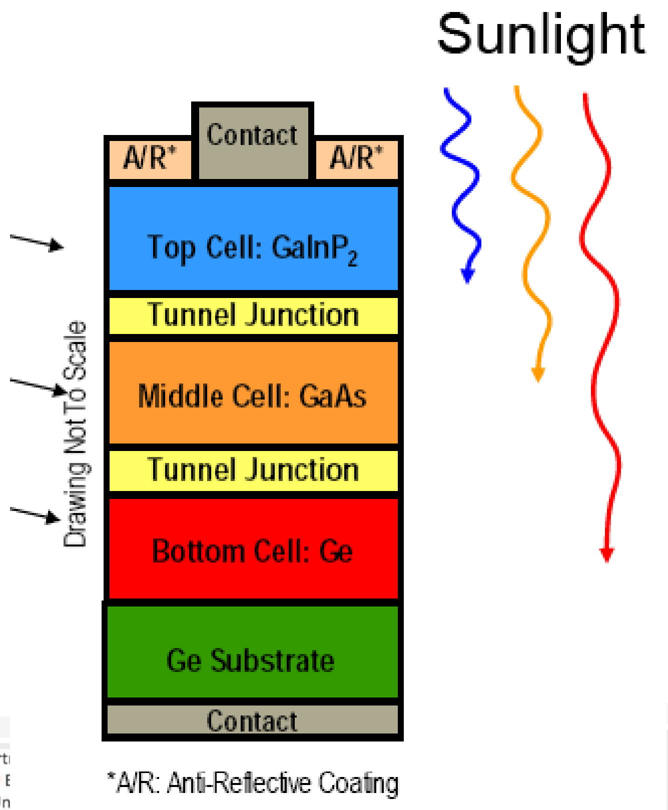
Wafer-based cells are fabricated on semiconducting wafers and can be handled without an additional substrate, although modules are typically covered with glass for mechanical stability and protection

Thin-film cells consist of semiconducting films deposited onto a glass, plastic, or metal substrate. Thin films can be further divided into commercial and emerging thin-film technologies.

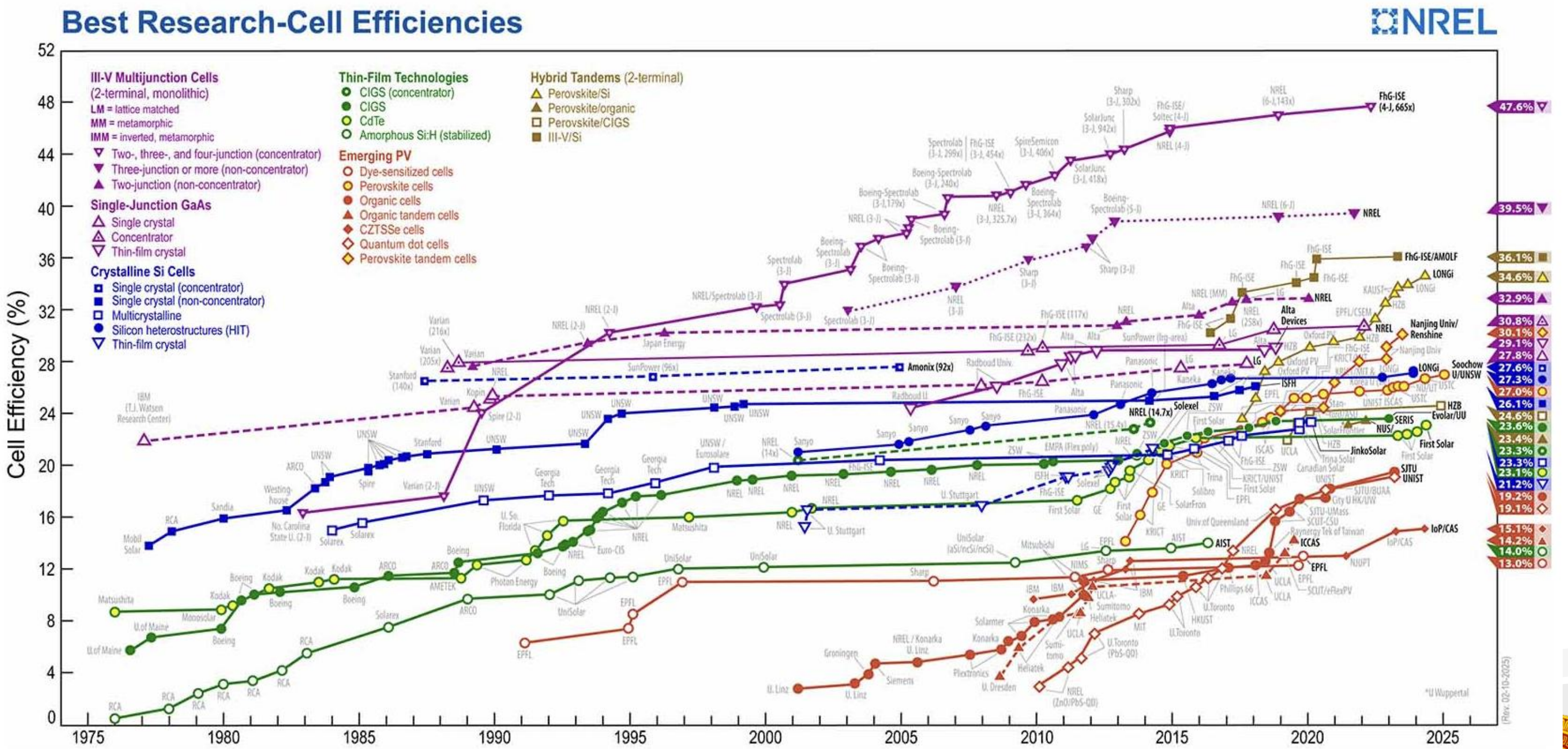


Source:Joel Jean et.al, “Pathways for solar photovoltaics”, Energy Environ. Sci., 2015, 8, 1200

Multi-junction PV cells



Cell efficiencies

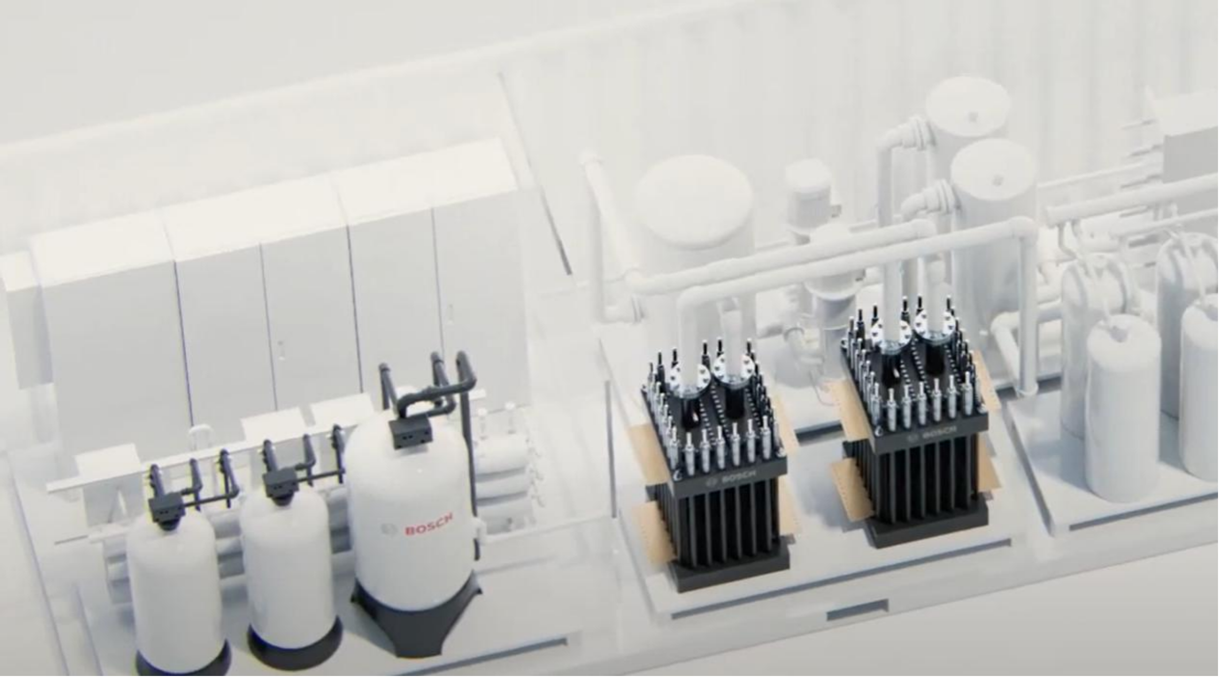


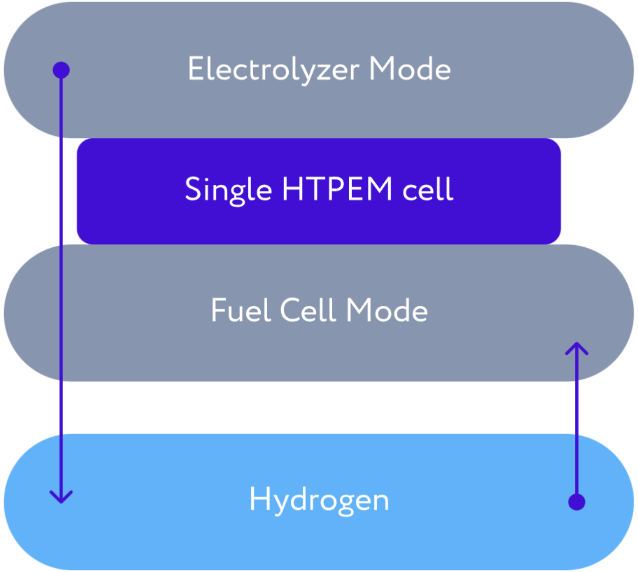
[Best Research-Cell Efficiency Chart | Photovoltaic Research | NREL]

Cost of Renewables and ES

BloombergNEF

Hydrogen solutions





HyWatts

- 23 kg of H_2 per hour; pressure of < 30 bar equivalent to 1.25 MW

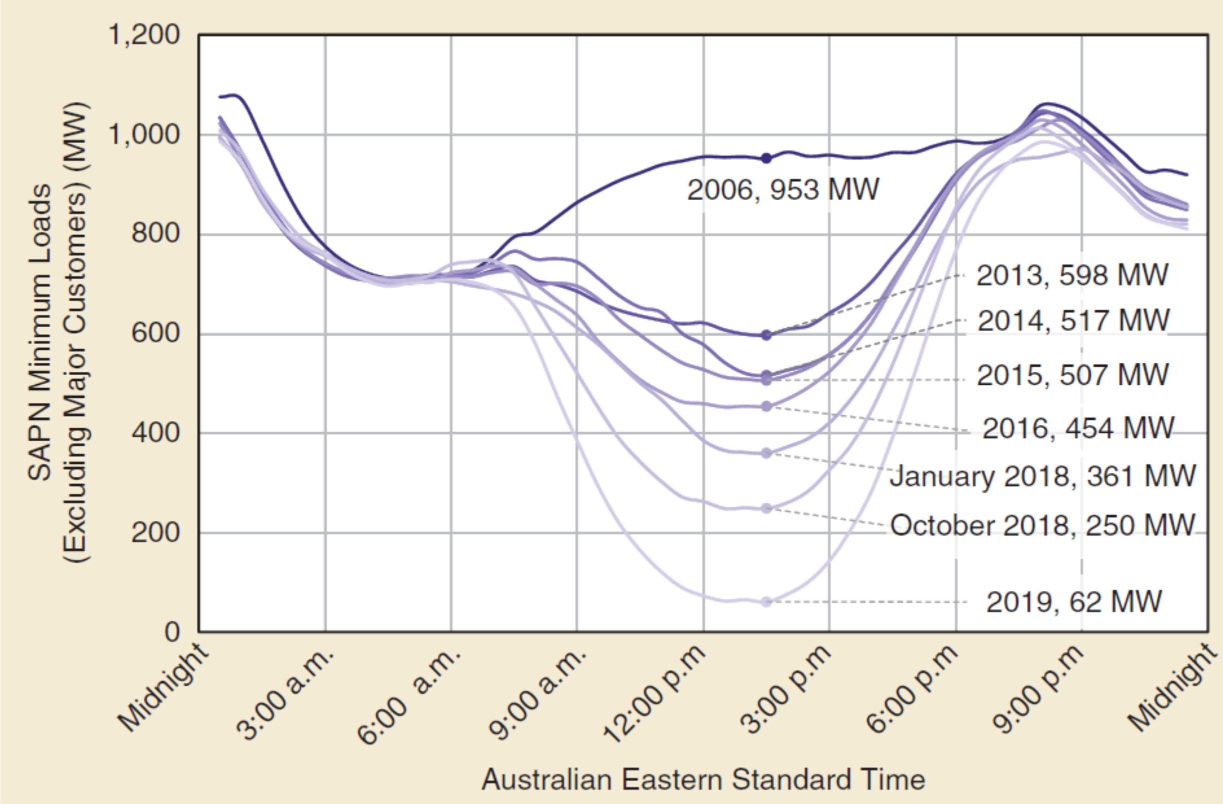
Record share of high VRE

- Year 2020 was special → Demand decreased due to COVID thus many systems operated with high wind and solar share
  - Denmark → VRE exceed the demand for 845 hrs ; Extreme case was VRE - 3637 MW and Demand - 1041 MW
  - South Australia → 77% of PV generation was from distributed PV
  - Tasmania → In January 2021, more than 90% is nonsynchronous penetration
  - Ireland & Northern Ireland → In January 2021, 95% of the demand met by renewables

CONNECTION ISSUES AND SOLUTIONS

Network operational issues

Net Demand



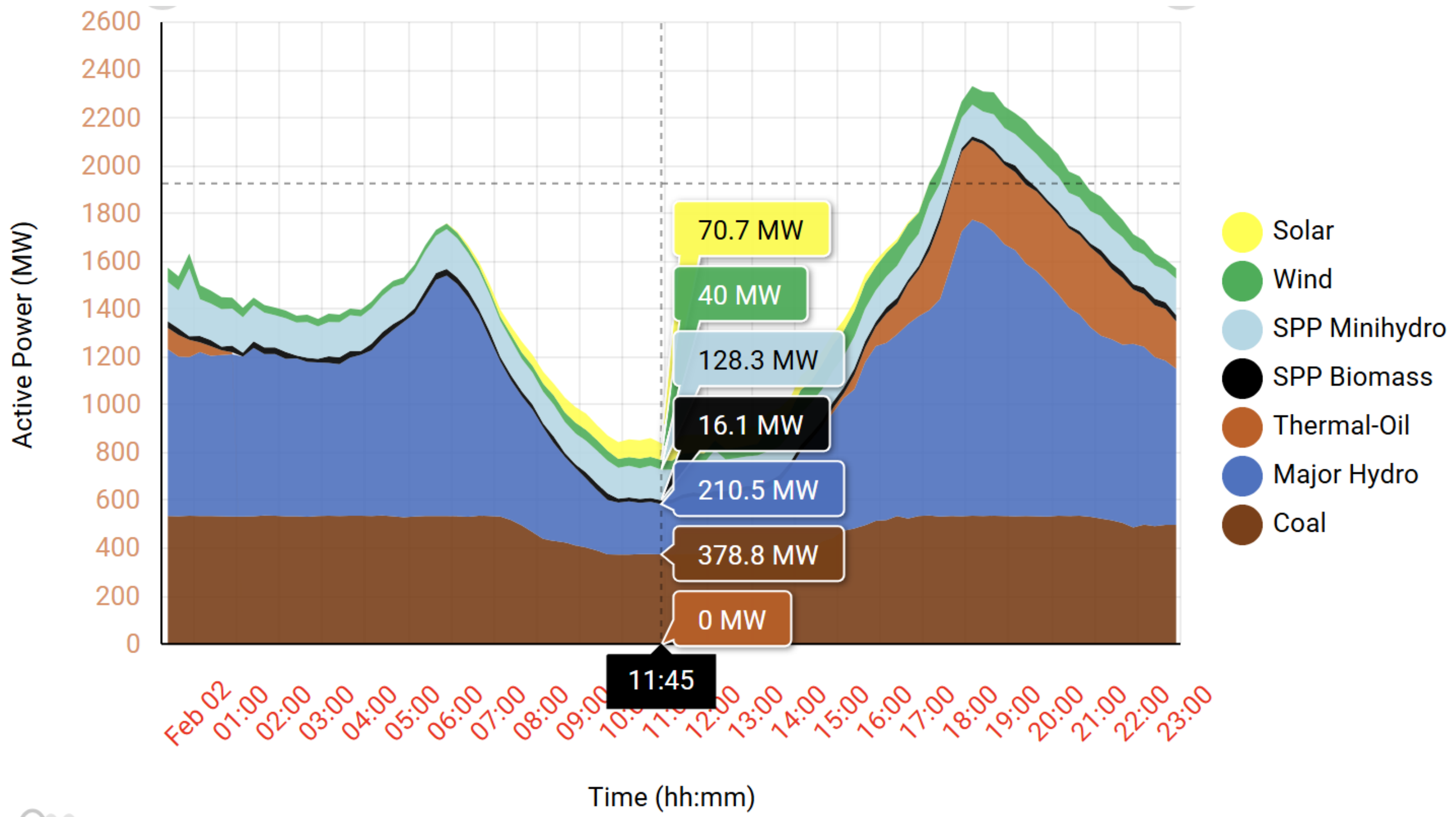
With more and more PV addition the net demand will not be visible to system operators

Some inflexible power plants need to be turned off for a longer period

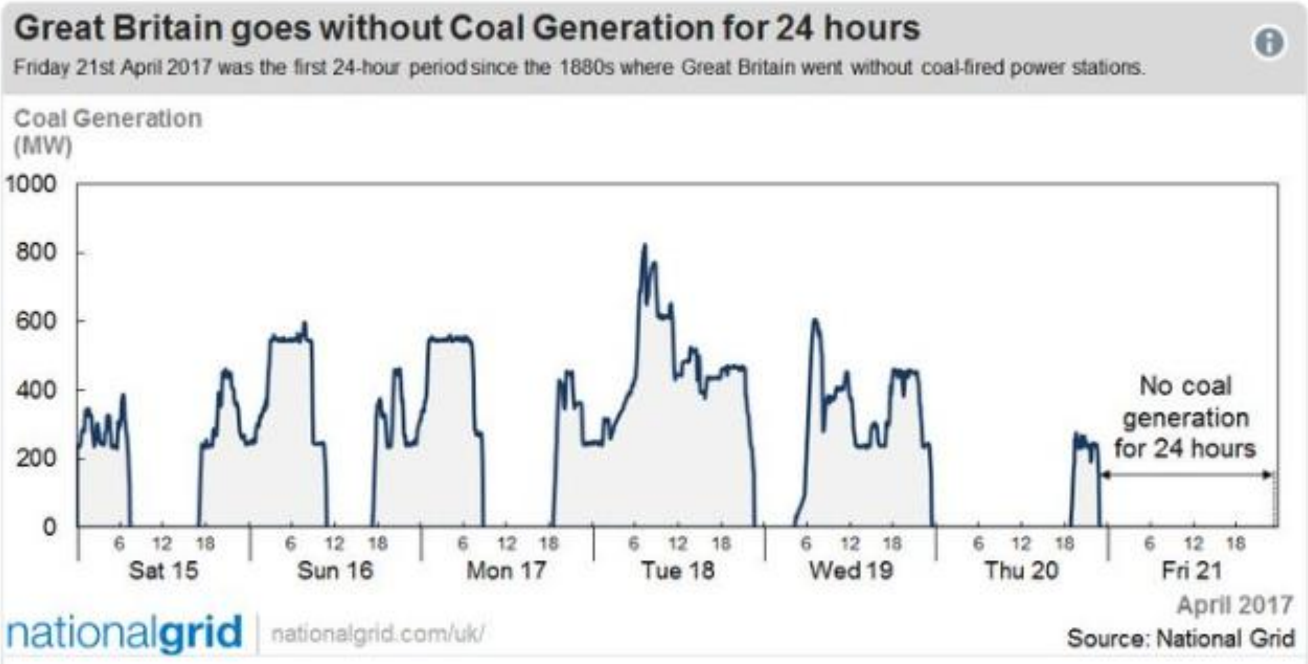
Consumer-Led Transition, IEEE Power & Energy magazine, Nov/Dec 2020

South Australian Network – Minimum net demand days

Net demand on 02/02/2025



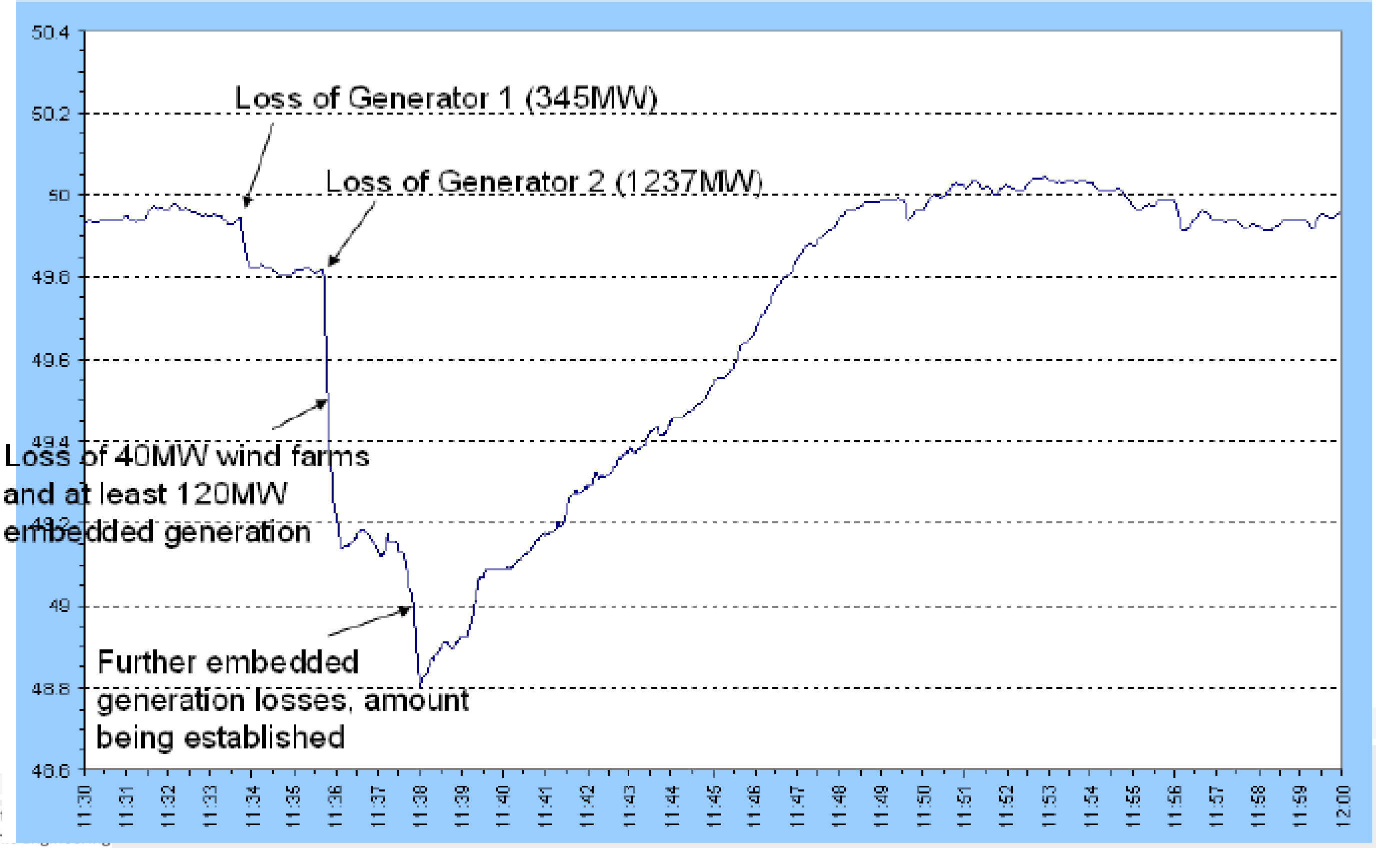
Impact on inflexible power plants



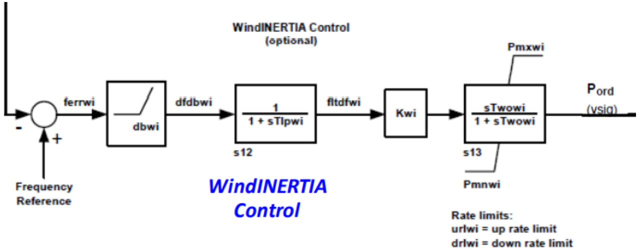
Renewables make some inflexible power plant to be shut-down for high wind or high-irradiance period

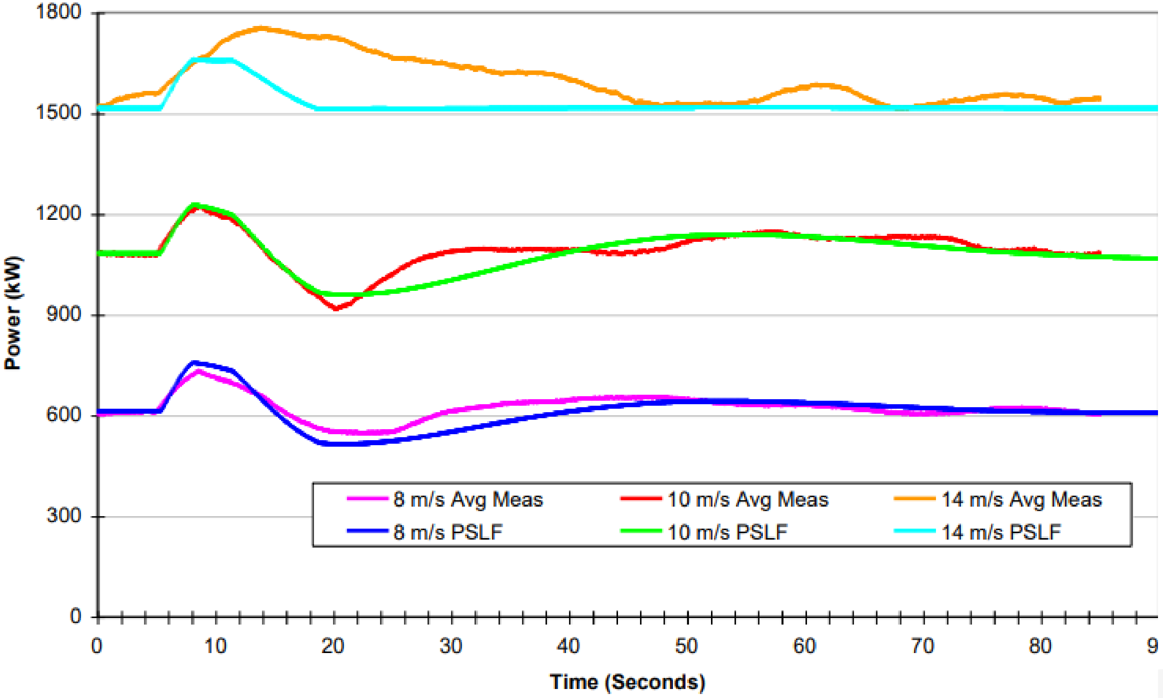
Frequency response to disturbance

Frequency event - 27 May 2008 - London

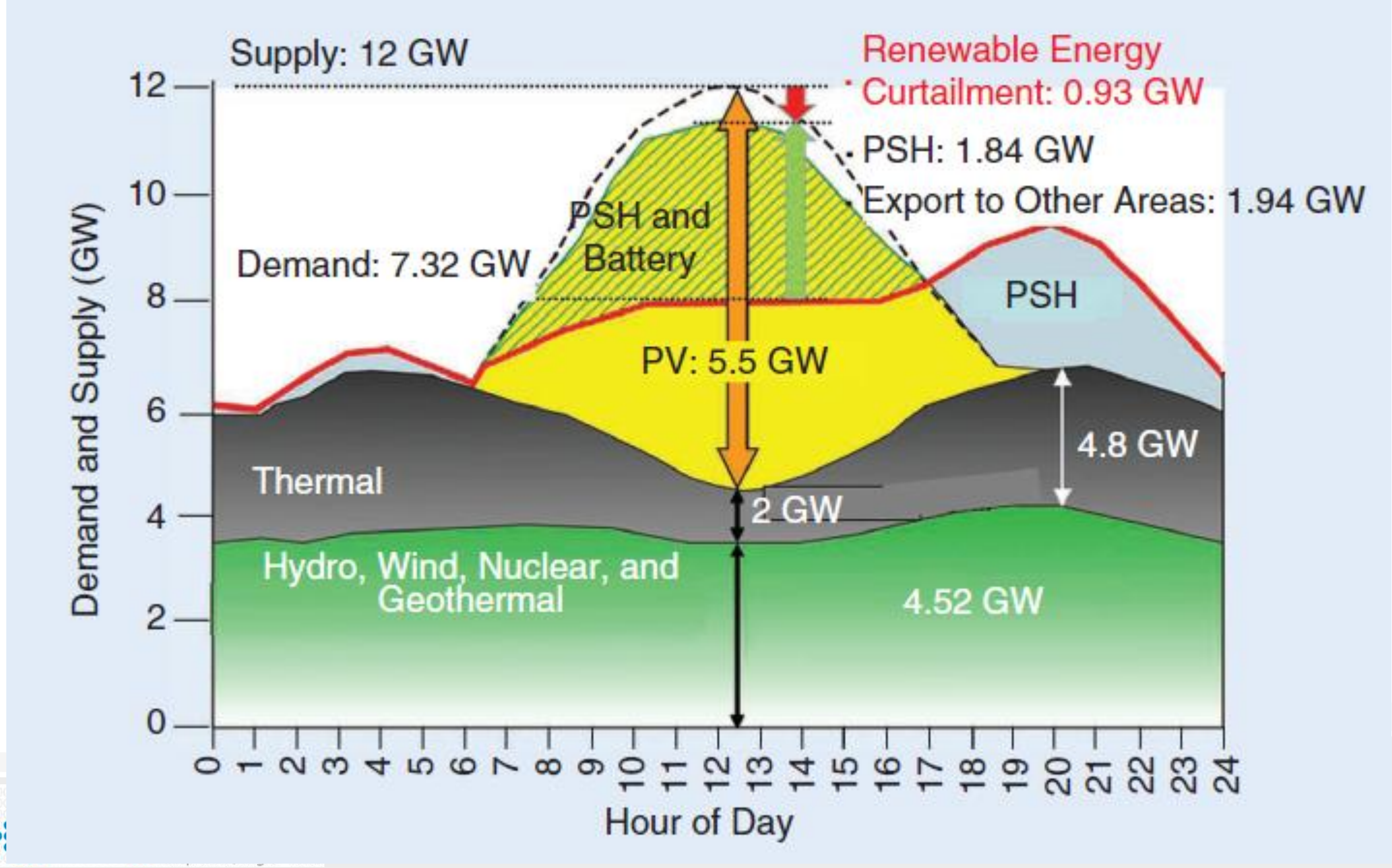


Wind turbine synthetic inertia



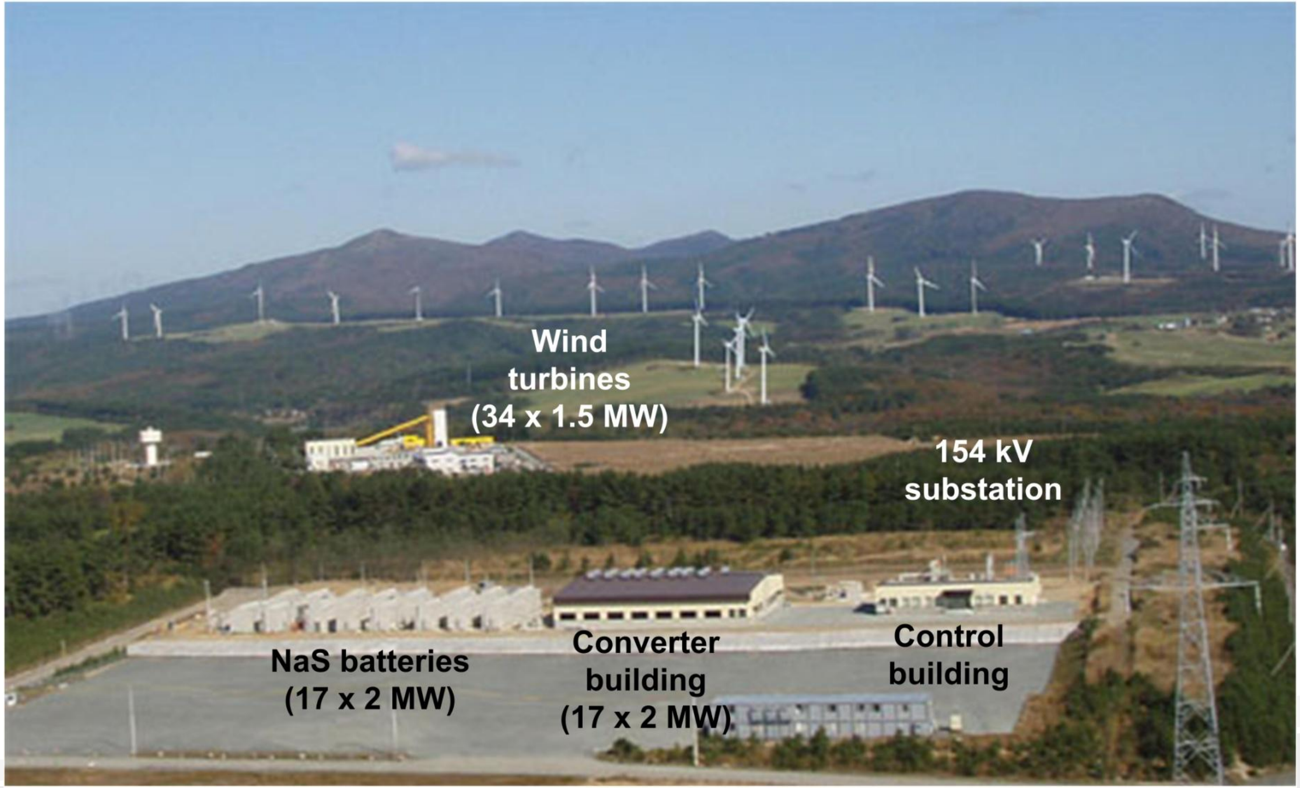


Solutions – Centralized Energy Storage



Making Renewables Work, Kazuhiko Ogimoto and Hiroshi Wani, IEEE Power & Energy Magazine, Nov/Dec, 2020

Solutions – Centralized Energy Storage



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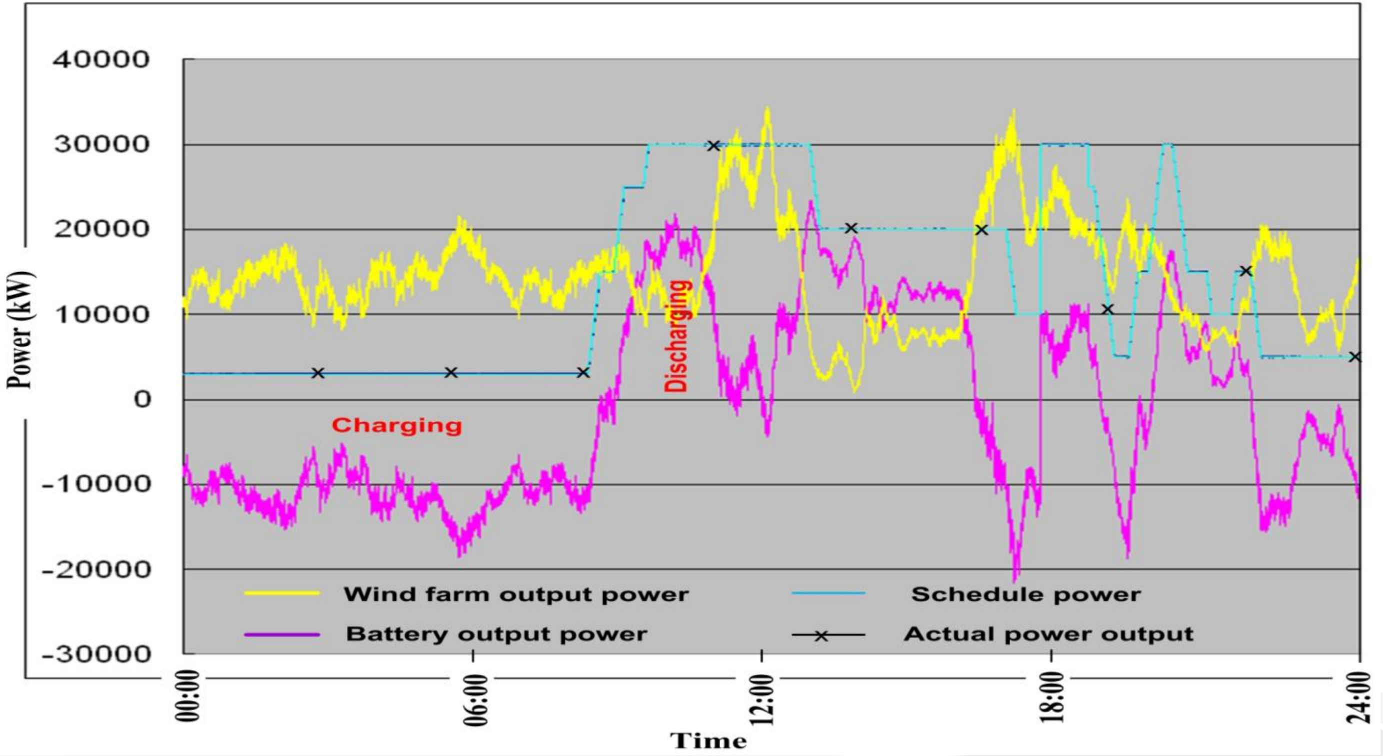
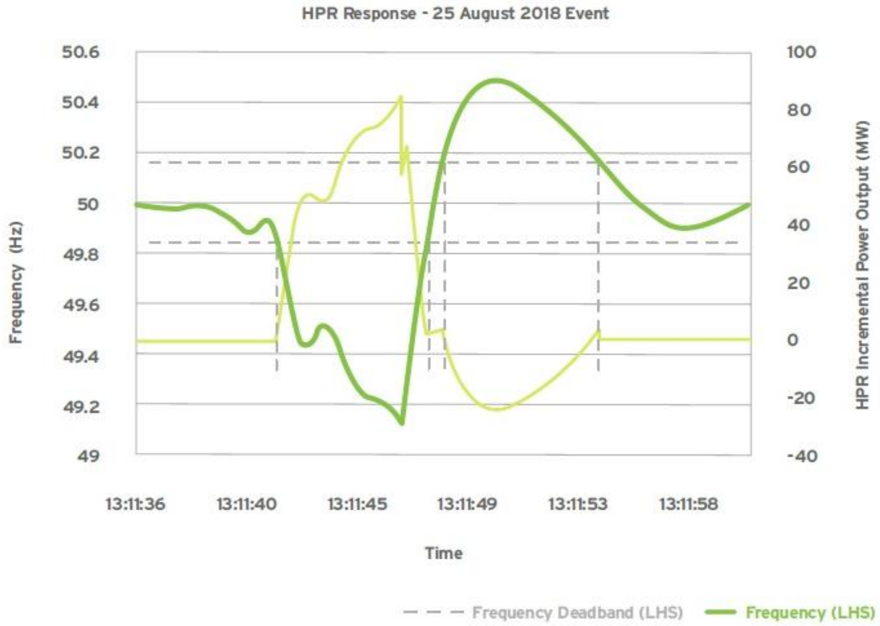
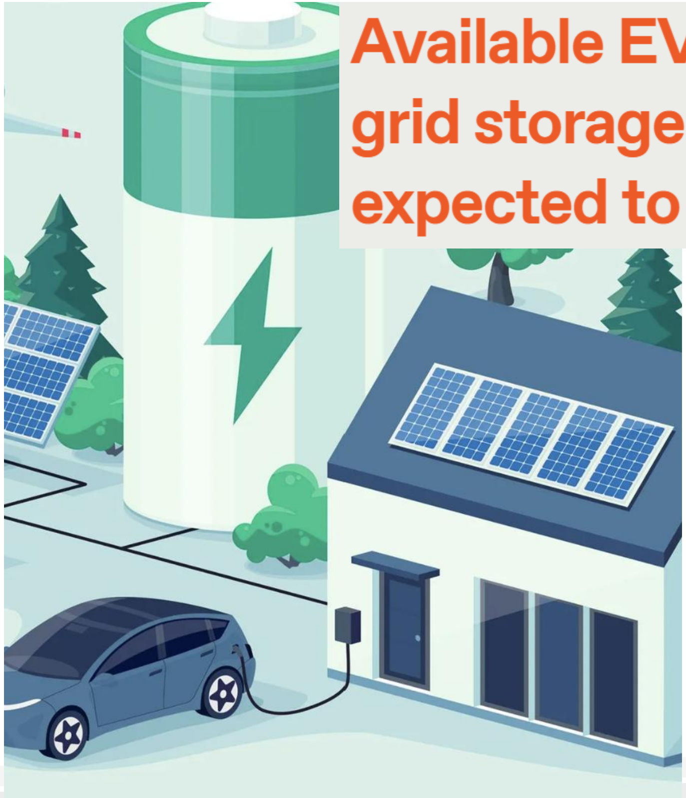


Battery response



Solutions – Decentralized Energy Storage



Available EV battery capacity—projected vehicle-to-grid storage plus end-of-vehicle-life battery banks—is expected to outstrip grid demands by 2050.

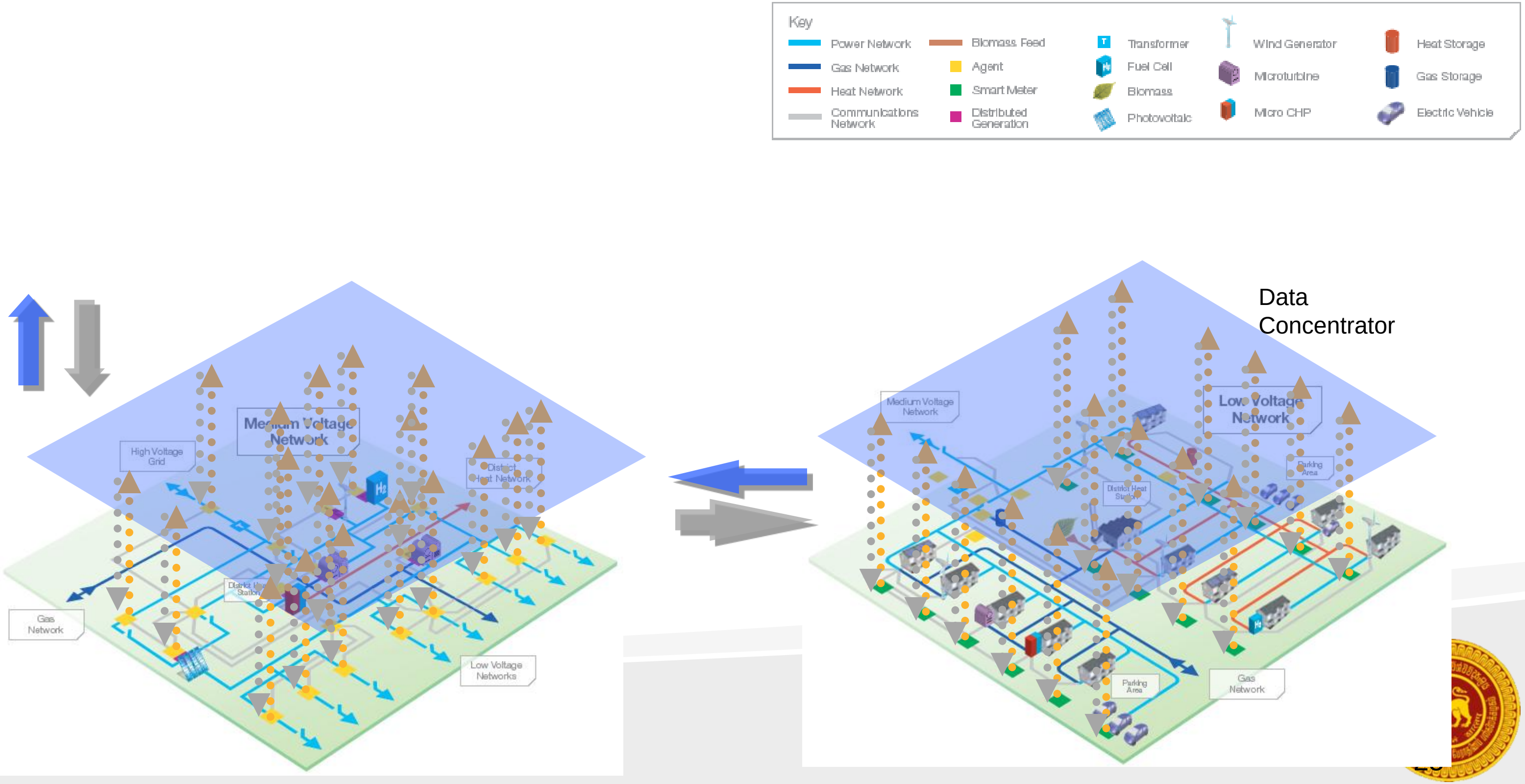
IEEE Spectrum

Standards Australia recently updated the national technical standard – known as AS4777 – relating to V2G chargers

Currently, only three cars on sale in Australia support V2G:

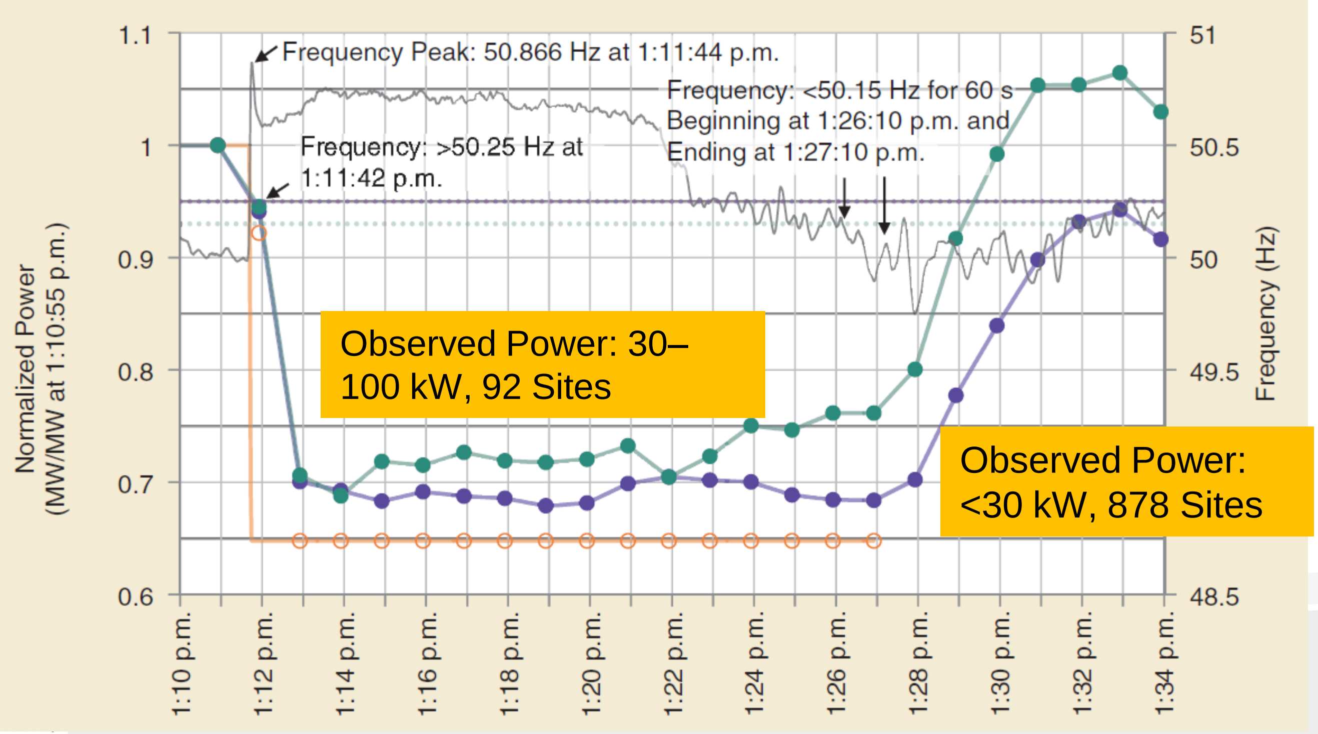
- Nissan Leaf
- Mitsubishi Outlander plug-in hybrid vehicle (PHEV)
- Mitsubishi Eclipse Cross (PHEV)

Harnessing V2G operation



Solutions – Decentralized PV support

- Operational data from more than 3,000 D-PV systems during a major system disturbance on 25 August 2018

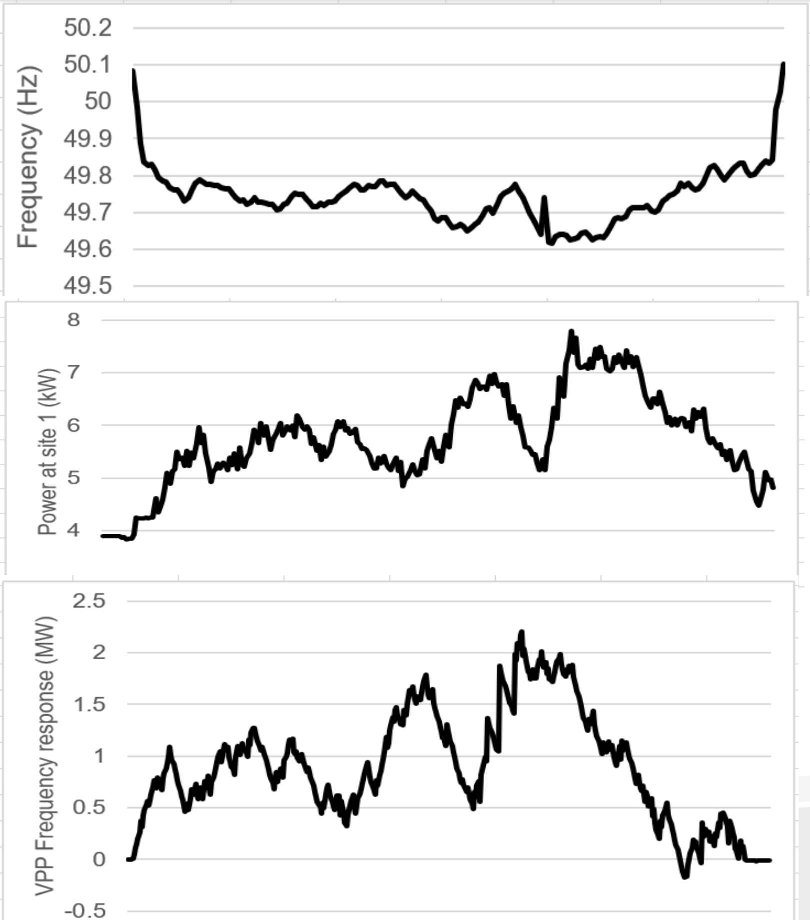


Virtual Power Plant (VPP)

Virtual Power Plant (VPP) trial of solar photovoltaic (PV) energy generation and battery storage technology with 100 residential customers in the metropolitan suburb of Salisbury, South Australia

- 90 Tesla batteries (6.4kWh)
- 10 Samsung batteries (7.2kWh)
- New & existing solar (4kW average)
- Local Reposit controllers via customer internet Aggregate VPP

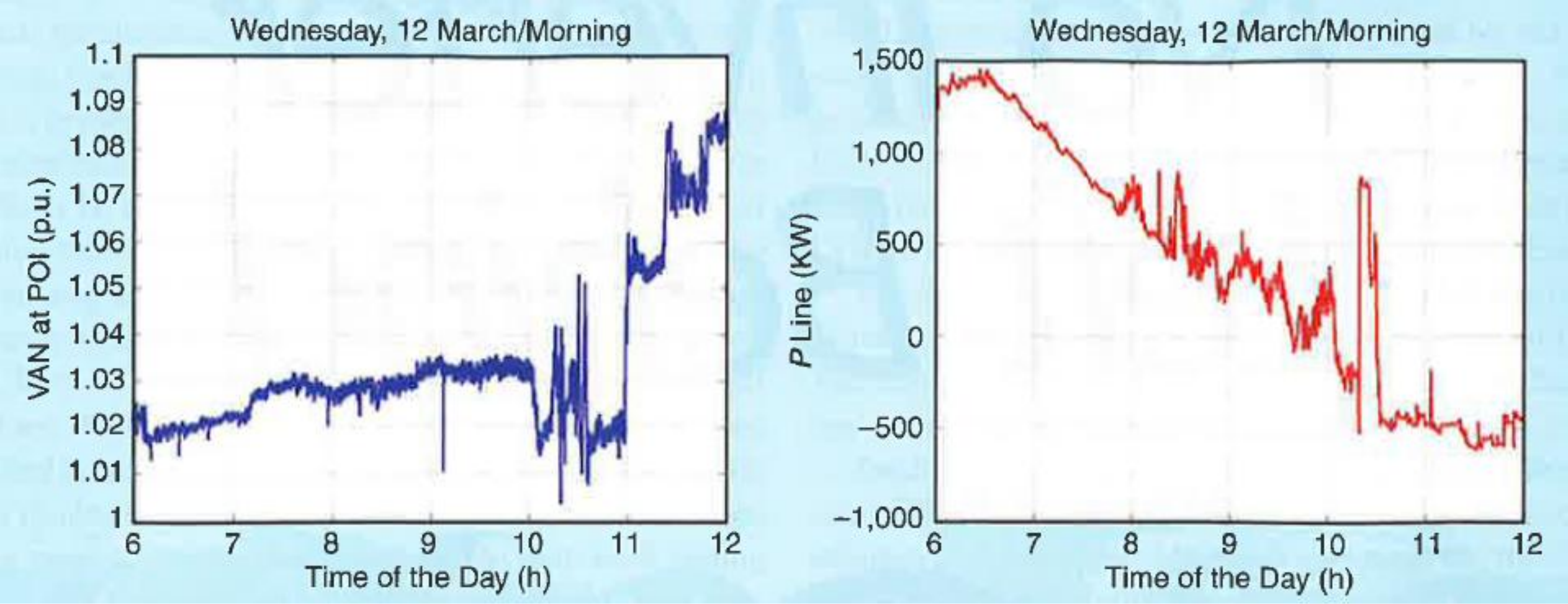
Virtual Power Plant (VPP)



CONNECTION ISSUES AND SOLUTIONS

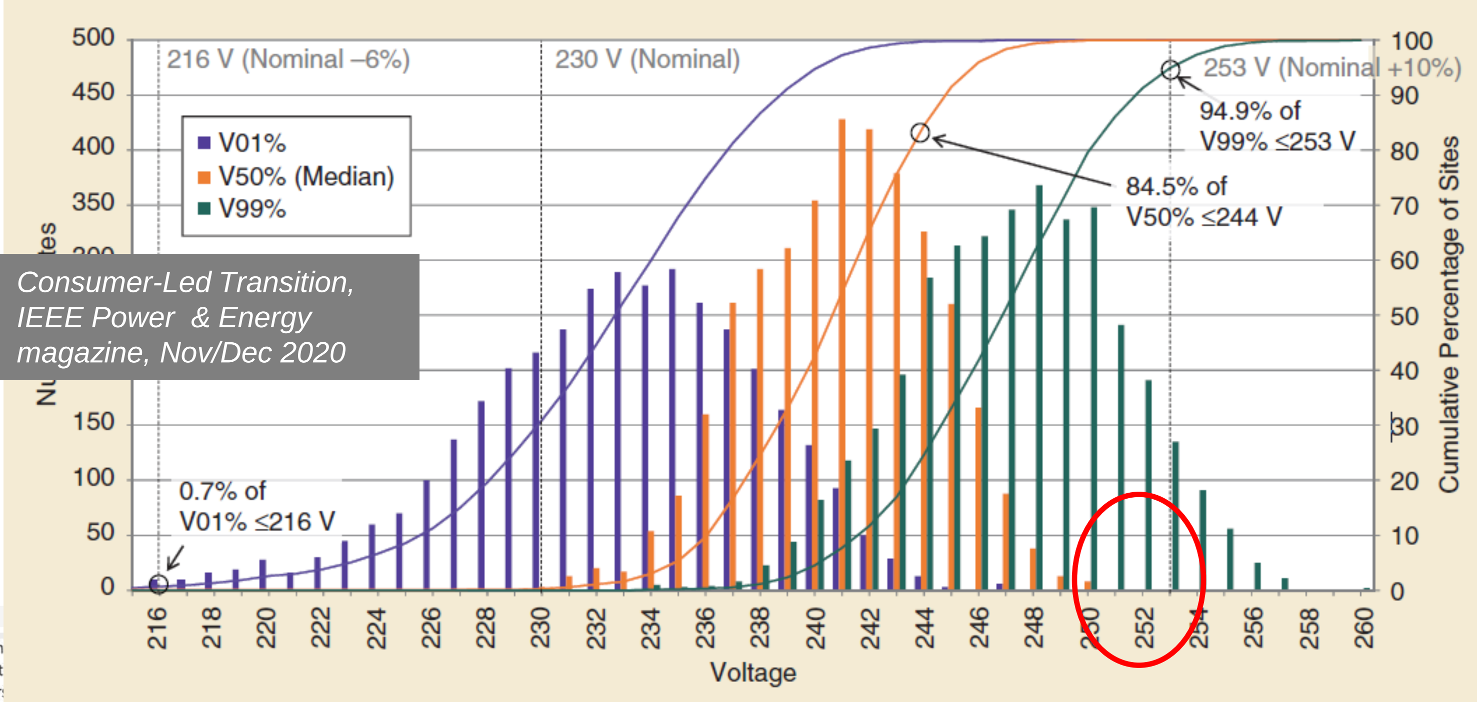
Network limit issues

Voltage rise in LV networks



Voltage rise in LV networks

- 1015 x 3, 10 min average voltage data point per site
- 4000 LV measurement sites
- 204 sites experienced voltages greater than statutory limit



Consumer-Led Transition, IEEE Power & Energy magazine, Nov/Dec 2020

Department
Elect
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Deep Vision, Bright Future

Smart inverter

Over 95% of the time full capacity of the PV inverter is not utilised

Unused capacity can be used to provide reactive power support for distribution network

Smart inverter can operate in 4 modes as described by IEEE1547:2018

Distributed Control

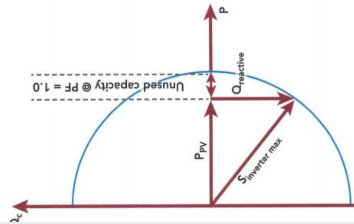
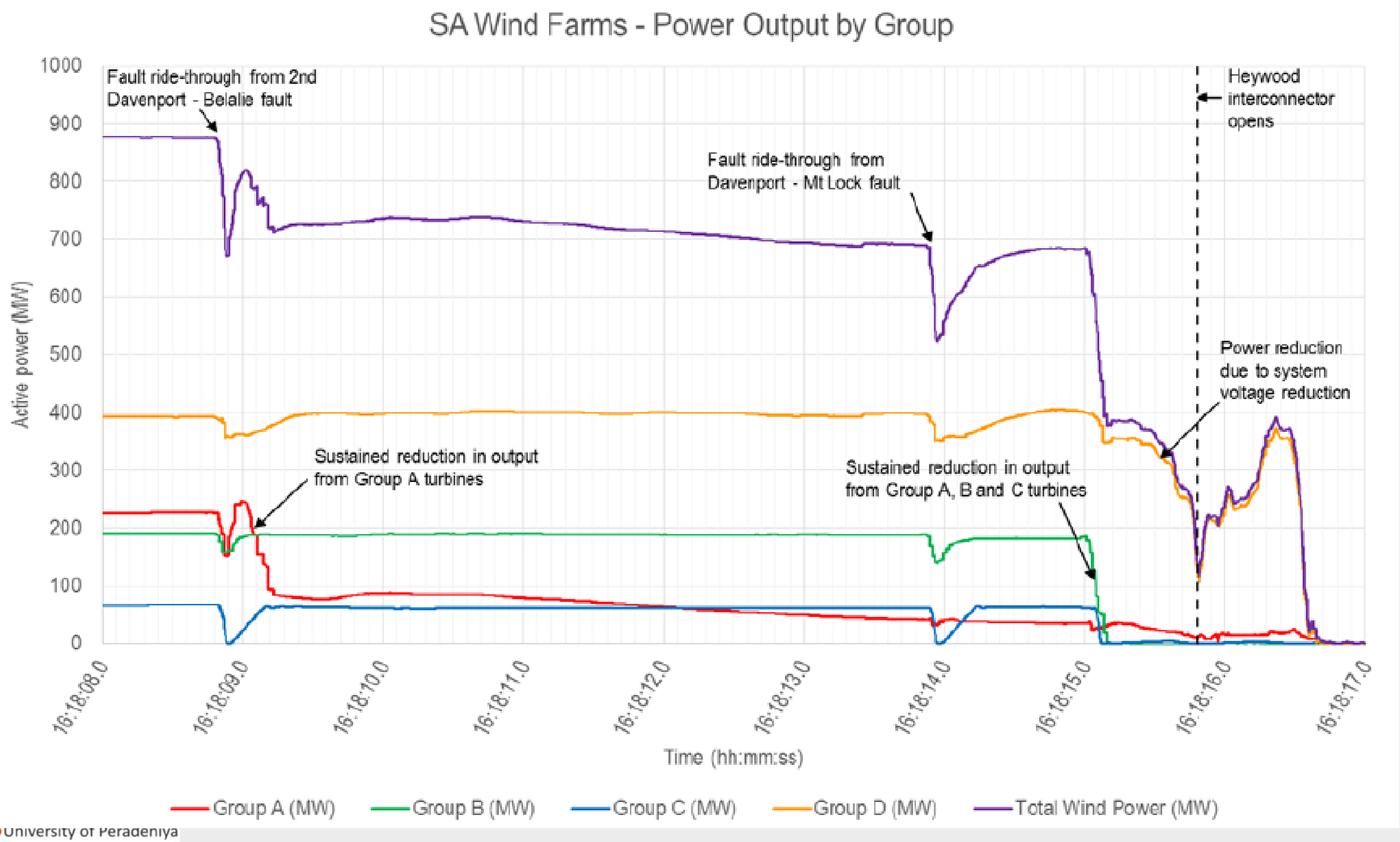


Figure 1. 2-Quadrant operation of the smart PV inverter

CONNECTION ISSUES AND SOLUTIONS

Blackouts

South Australia Blackout - 28 Sep 2016



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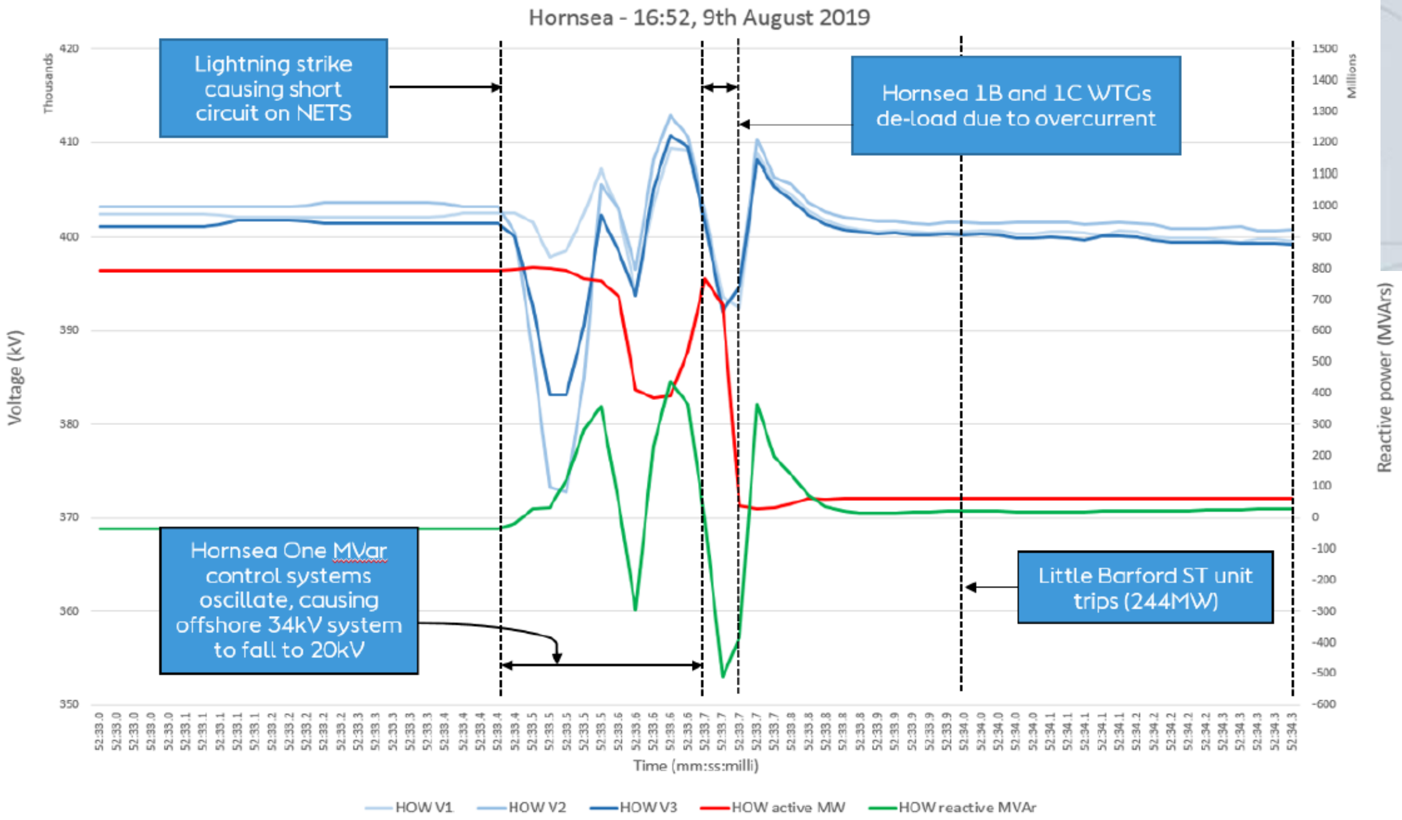
London Blackout - 9 August 2019



Sri Lanka Blackout – 9th Feb 2025

Solar inverters are set to disconnect from the grid, under the following conditions:

- **Voltage Fluctuations:** If the grid voltage exceeds or falls below acceptable limits, the inverter will disconnect to prevent damage to itself and other connected equipment.
- **Frequency Variations:** Similarly, if the grid frequency deviates from 50 Hz), the inverter will disconnect.
- **Grid Outage (Islanding):** In the event of a grid outage, the inverter must immediately disconnect to prevent "islanding," where the solar system continues to power the local grid, potentially endangering utility workers.

Post contingency analysis

- Detailed computer studies for possible contingencies

Slots BlkSlot	Net Elements Elm*,Sta*,IntRef
Generator	WTG 1.2
Slow PLL	Slow Freq Measurement 1.2
PQ Control	PQ Controller 1.2
PQ	PQ Measurement LV 1.2
Vac	Voltage Measurement 1.2
Current Controller	Current Controller 1.2
Iac	Current Measurement 1.2
PLL	PLL 1.2
ActivePowerReduction	OverFrequPowerReduction 1.2

Name: PQ Controller 1.2

Model Definition: ... MW\Library\WT Model\PQ Control

Out of Service

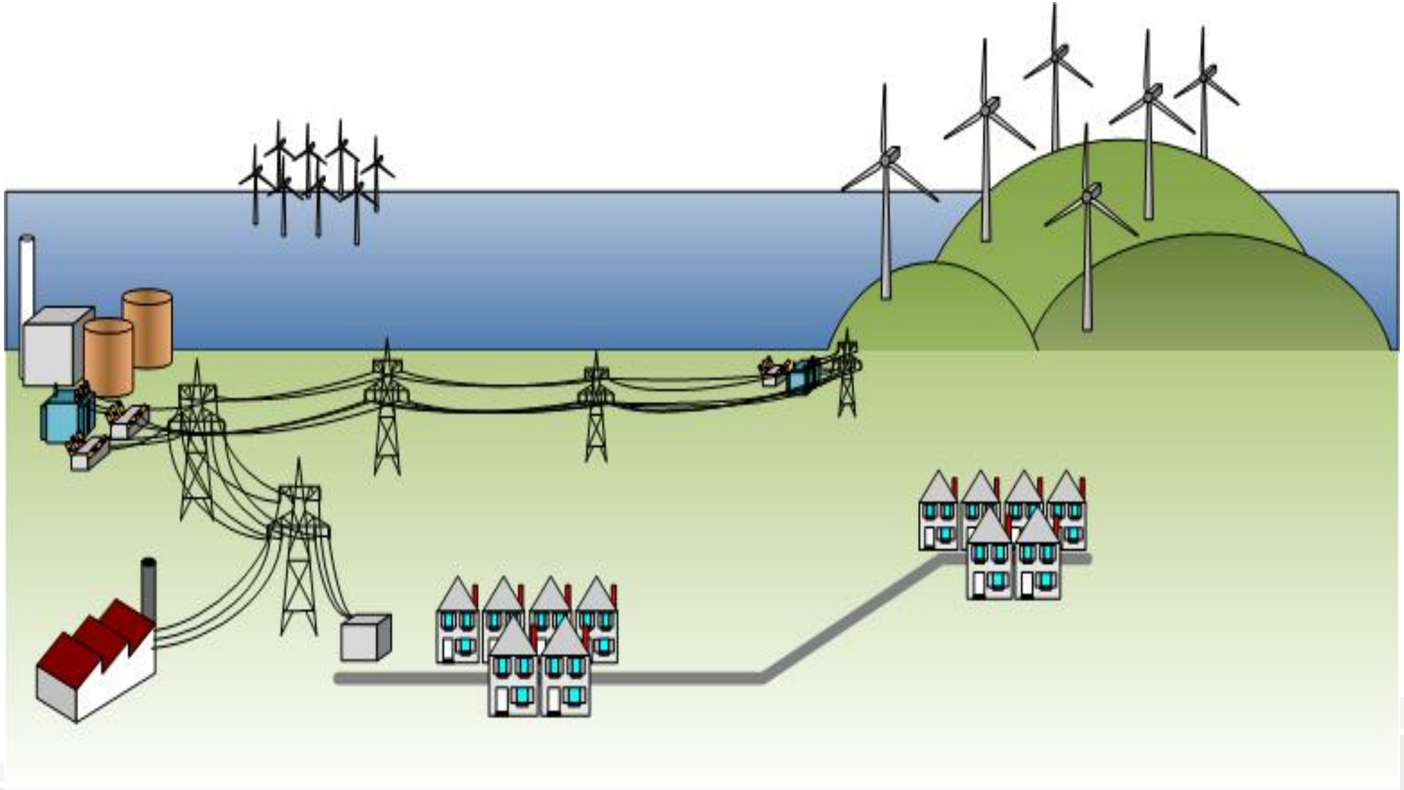
A-stable integration algorithm

	Parameter
Kp : Active Power Control Gain [p.u.]	0,5
Tp : Active Power Control Time Constant [s]	0,002
Kq : Reactive Power Control Gain [p.u.]	0,5
Tq : Reactive Power Control Time Constant [s]	0,02
deltaU : Voltage Dead Band [p.u.]	0,1
i_EEG : 0 = acc. TC 2007; 1 = acc. SDLWindV	1,
Tudelay : Voltage Support Delay [s]	0,01
K_deltaU : Reactive support gain	2,
i_max : Combined current limit [p.u.]	1,
ramp : Active Power Ramp for TC 2007 Mode [%/s]	500,
u_max : max. allowed internal voltage [p.u.]	1,1
X : Coupling Reactance [%]	10,
id_max : id current limit [p.u.]	1,
iq_max : iq current limit [p.u.]	1,

NON-TECHNICAL BARRIERS FOR RENEWABLE ADDITIONS

SYSTEM-LEVEL SOLUTIONS FOR RENEWABLE ADDITIONS

Electrical power system



What is the Smart Grid?

- **European Technology Platform defines the Smart Grid as:**
  - *A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.*
- **According to the US department of Energy:**
  - *A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources*

What is the Smart Grid?

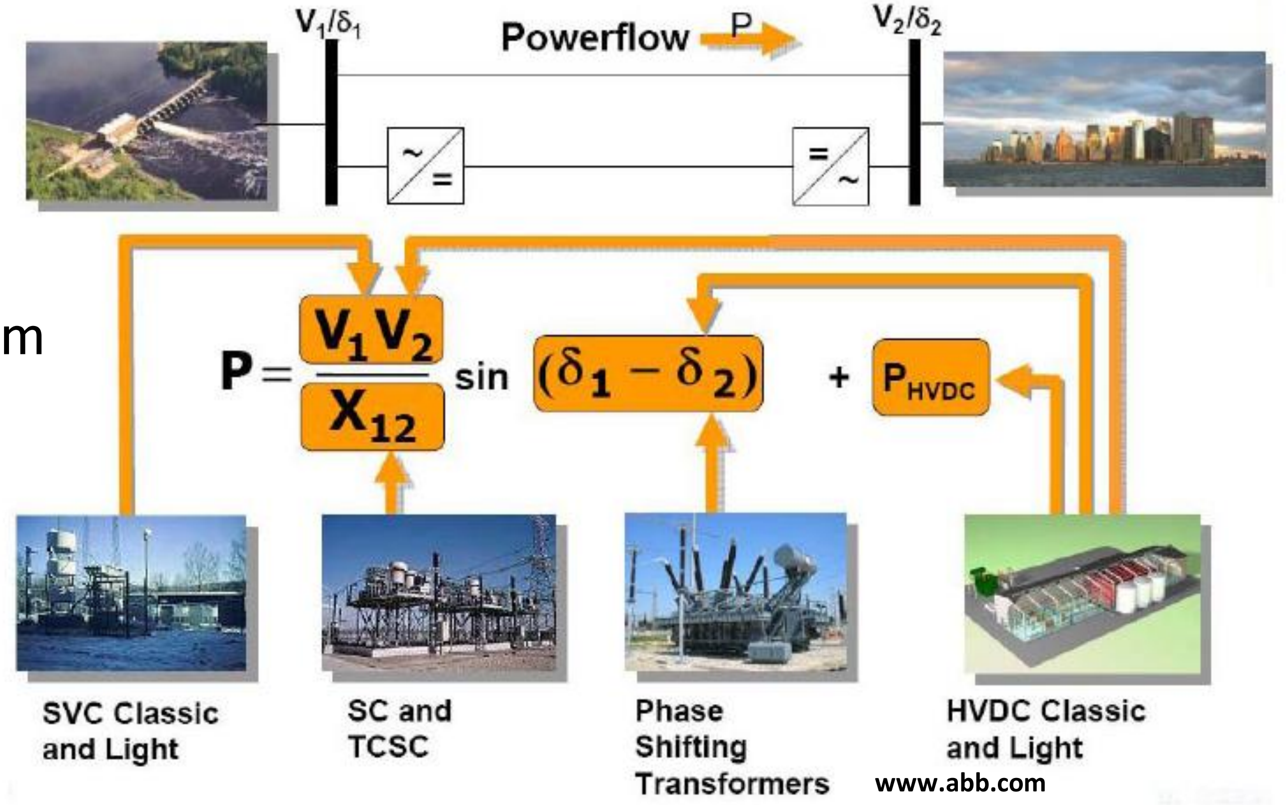
- **According to a document on Smarter Grids by the Department of Energy and Climate Change, UK:**
  - *A smart grid uses sensing, embedded processing and digital communications to enable the electricity grid to be observable (able to be measured and visualized), controllable (able to manipulated and optimized), automated (able to adapt and self-heal), fully integrated (fully interoperable with existing systems and with the capacity to incorporate a diverse set of energy sources).*

The Smart Grid will

- Enable real time visualisation of the power system
- Support enhancement of power system security
- Relieve system bottlenecks
- Enable self-healing systems
- Enable connectivity to consumers

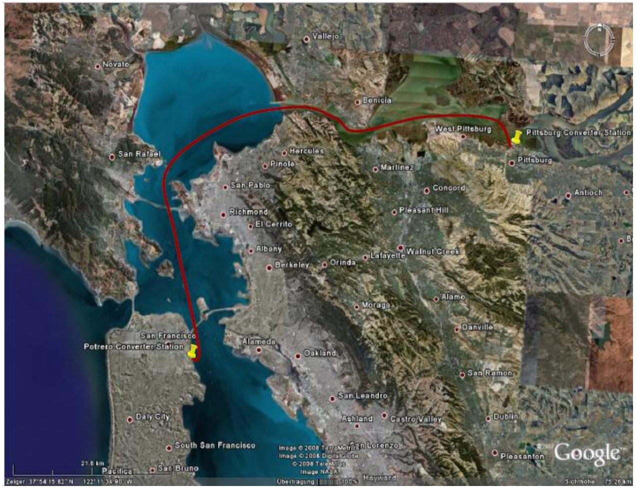
Power Electronics

Relieve system bottlenecks



www.abb.com

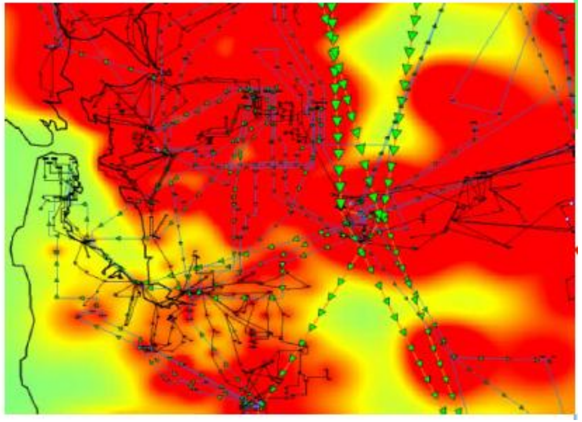
Relive system bottlenecks



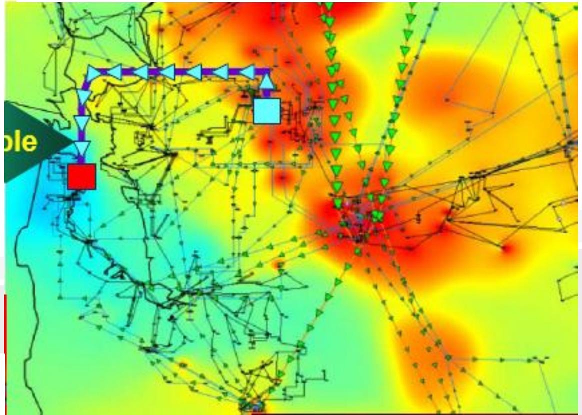
HVDC link between Pittsburg and San Francisco

- 400 MW, ±200 kV
- HVDC PLUS using IGBT

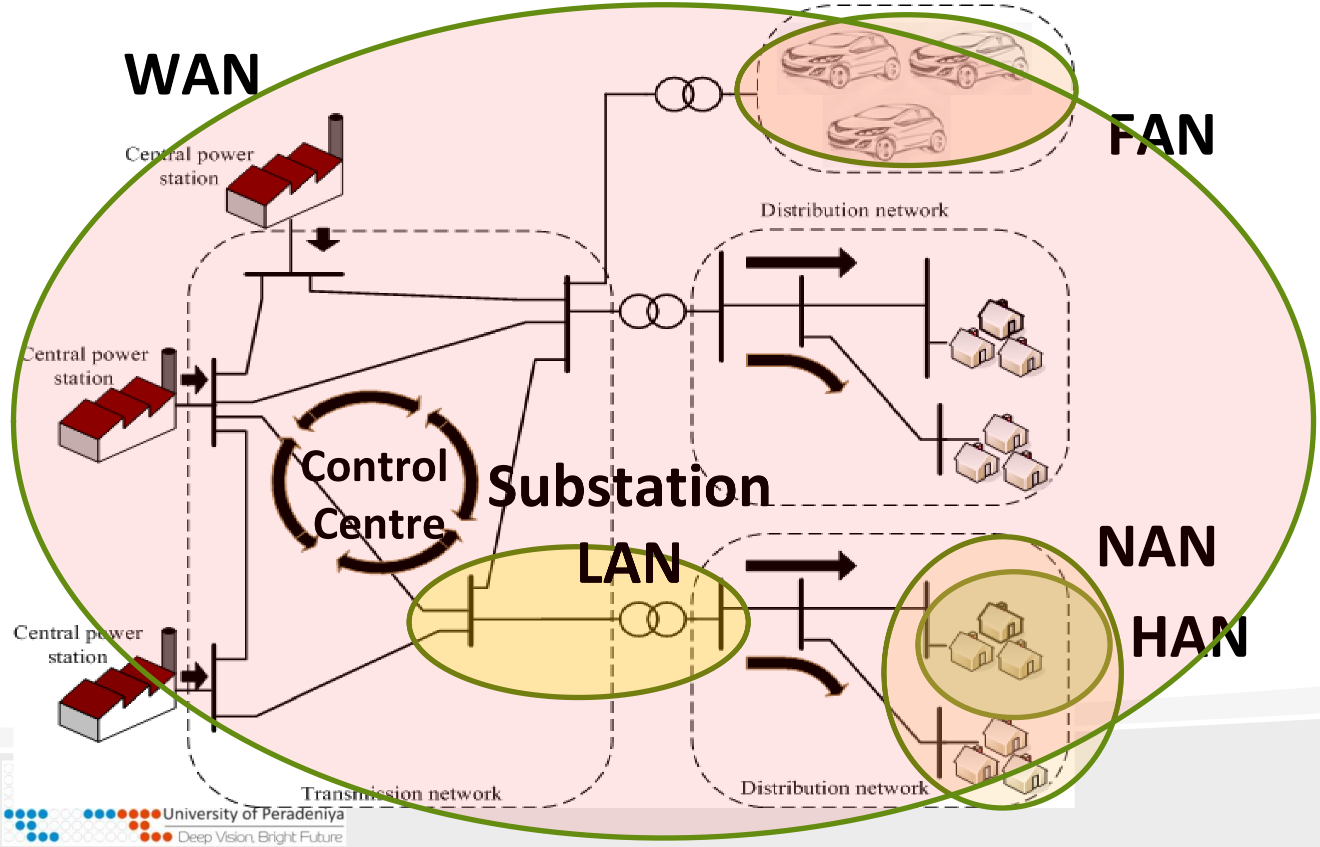
Transmission Constraints before TBC



Transmission Constraints after TBC



ICT infrastructure



Substation LAN:
IEC61850

NAN, FAN:
IEEE 802

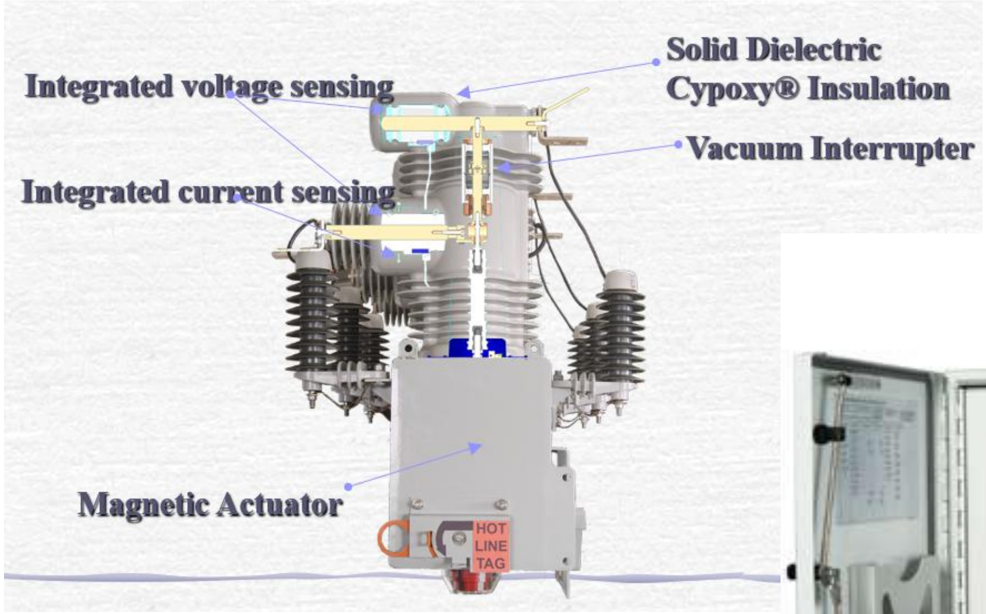
Zigbee and 6LoWPAN:
IEEE 802.15.4

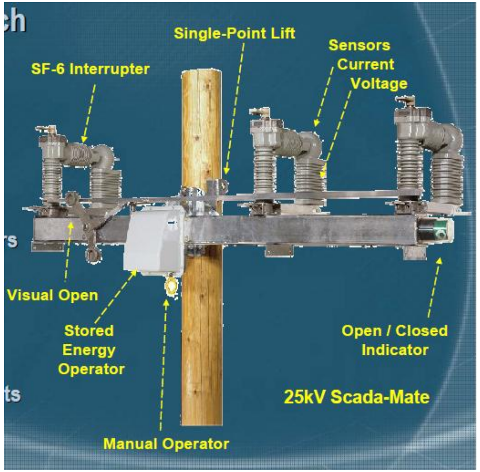
Power Line Communication:
IEEE P1901

Distribution Automation

An Agent is employed that gathers data from all the intelligent devices in the system. During normal operation, the Agent polls all the RTUs and IEDs to establish the system status.

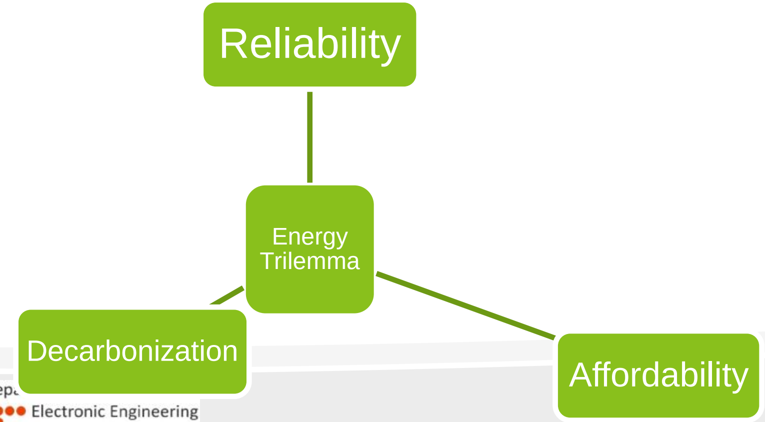
Distribution Automation





Concluding remarks

- Even though there are issues for renewable additions in all voltage levels in power system, there are possible solutions to mitigate them.
- The selection and adaptation of mitigation actions mainly depend on economics and policies in place.



Considering the economics, the following are some possible solutions we could consider

- Controlling PV inverters for voltage and frequency regulations
- Using EV as a distributed energy storage

These solutions demand Smart metering infrastructure, and it is essential to consider the cost of local action vs central actions.

Questions @ Q & A



Thank you for listening