Coping Mechanisms for Massive Variable Renewable Energy Deployment in Asia-Pacific Power Systems

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160,000 employees
140 Bn€ turnover (2023)
37 gCO2/kWh carbon intensity for generation
Shift from carbon-intensive generation to VRE: challenges of intermittency and regional reliance on coal and gas complicate grid stability in Asia-Pacific.
Mechanisms to facilitate VRE integration

- Expansion and strengthening of the existing power system
- Regulatory framework
- Improved flexible generation capacity and power generators
- Energy storage
- Demand response and energy efficiency programs
- Improved grid flexibility
- Smart grid technologies
- Power system market structure

Focus on:
- Singapore
- Japan
- Australia
1 Singapore
Singapore - State of Solar PV

- Limited renewable energy options
- Solar irradiance of 1,580 kWh/m²/year
- Grid-connected installed solar capacity grew significantly from 125.0 MWp in 2016 to 670.0 MWp as at end Q1 2022.
- A total of 5,455 solar PV installations in Singapore as at end Q1 2022
- As of March 2022, Solar PVs represents 4.2% of the total generation capacity in Singapore
- SG aims to deploy at least 2 gigawatt-peak (GWp) of solar energy by 2030
Singapore

- **SP PowerAssets** maintains, operates and enables the secure operation of the transmission system. It is also responsible for the secure operation of the distribution network.
- The **Power System Operator (PSO)** is responsible for the secure operation of the transmission network and all centrally dispatchable generating units.
- SPPA is required to plan and develop its electricity transmission and distribution network, which are subject to endorsement by PSO and approval by EMA.
- SPPA guides the installation of EV charging stations, small-scale PV, and small-scale batteries connected to distribution networks.
- The PSO is responsible for the coordination of outages in the NEMS, conducting an annual outage planning process, and preparing the Singapore Electricity Emergency Plan and the Singapore Power System Restoration Plan.

The installed PV capacity has **not** yet been a challenge to the utility network, due to the following facts:

- The Singapore power network is of high reliability and redundancy.
- The PV penetration level is low.
- The combined-cycle gas turbines used in Singapore are flexible to accommodate more PV output.
- Regulation
- Other factors, such as Energy Storage System, interruptible load and Demand response.
Japan
Japan – State of solar PV

- In 2021, 31% overall renewables share
- PV represents 66% of renewables
- Annual installed PV capacity reached 6545 MW, including 830 MW in the residential sector (13%)
- Average RE curtailment rate at 0.3% in 2022
Japan – Distributed PV control solutions

Local congestions are one of the main issues for deploying renewable energies in Japan. Different solutions are used depending on the size of the PV installation.

At transmission level, PV power plants are required to be linked to large battery storage systems to mitigate output fluctuations to ensure grid stability. At distribution level, two methods are used:

- **Non-firm connection** for PV with capacity higher than 10kW (small commercial PV)
- **Smart-meters and Home Energy Management Systems (HEMS)** for PV under 10kW (residential)
Japan – System Planning and Operation at TSO and DSO

- Vertically and horizontally integrated system operation and planning within region
- Information exchange within the organization
- Integrated capital investment planning for the transmission and distribution
- Centralized Cross-regional Coordination of Transmission Operators for normal and emergency planning and operation
- Development within each regions are independent
- Development of common data platform for the information exchange between the TSO and DSO
- Uses grid visualization software for the transmission and distribution management
3 Australia
Australia – State of Solar PV

• As of 31 Dec 2022, there are over 3.36 million PV installations in Australia, with a combined capacity of over 29.7 gigawatts.

• Most of the PV systems in Australia are small-scale residential, and increasingly, commercial rooftop installations. There are also a growing number of larger-scale PV power stations with a capacity of 100kW or more.

• The maximum instantaneous share of renewable energy generation in the National Electricity Market (NEM) reached a new record high in Q4 2022 at 68.7%.
Australia – Technical measures for integration of DER

The grid was originally designed for a one-way flow of power from large-scale centralized generation. Integrating small-scale and decentralized generation into the system requires significant changes to be made to infrastructure, regulations and markets.

Technical measures taken in Australia for integration of DER include:

- Standards for voltage management
- DER market trials

Active management: Emergency Backstop Mechanism (QLD, SA, WA), dynamic export limit (QLD, SA, VIC)
Australia – TSO/DSO coordination

• Australia has a high renewable penetration level, where rooftop PV takes an important role.

• The coordination among various stakeholders is crucial for the evolution of Australia’s network.

• Australian Energy Market Operator (AEMO) publishes the Integrated System Plan (ISP), which Transmission Network Service Providers (TNSPs) use to develop projects to meet the requirements of the ISP.

• Distribution Network Service Providers (DNSPs) is responsible for distribution planning.

• Different levels of joint planning in Australia: TNSPs with AEMO, among TNSPs, among TNSP and DNSP, among DNSPs, among DNSPs and relevant stakeholders.

• The coordination format varies, including regular meetings with different frequencies and purposes, forums, groups, etc.

• Different regions may have different formats of coordination among different parties, but all need to meet the rules set by Australian Energy Market Commission (AEMC)
Conclusion

Transitioning from centralized to decentralized generation requires significant infrastructure changes, voltage management standards, active management mechanisms, and DER market trials to integrate distributed energy resources effectively.

High reliability and redundancy of the power network, low PV penetration level, flexible combined-cycle gas turbines, stringent regulation, and factors such as energy storage systems and demand response help maintain stability.

Solutions vary by PV installation size, with large battery storage systems at the transmission level and smart meters and home energy management systems at the distribution level to manage local congestions.

Singapore, Japan, Australia.
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