



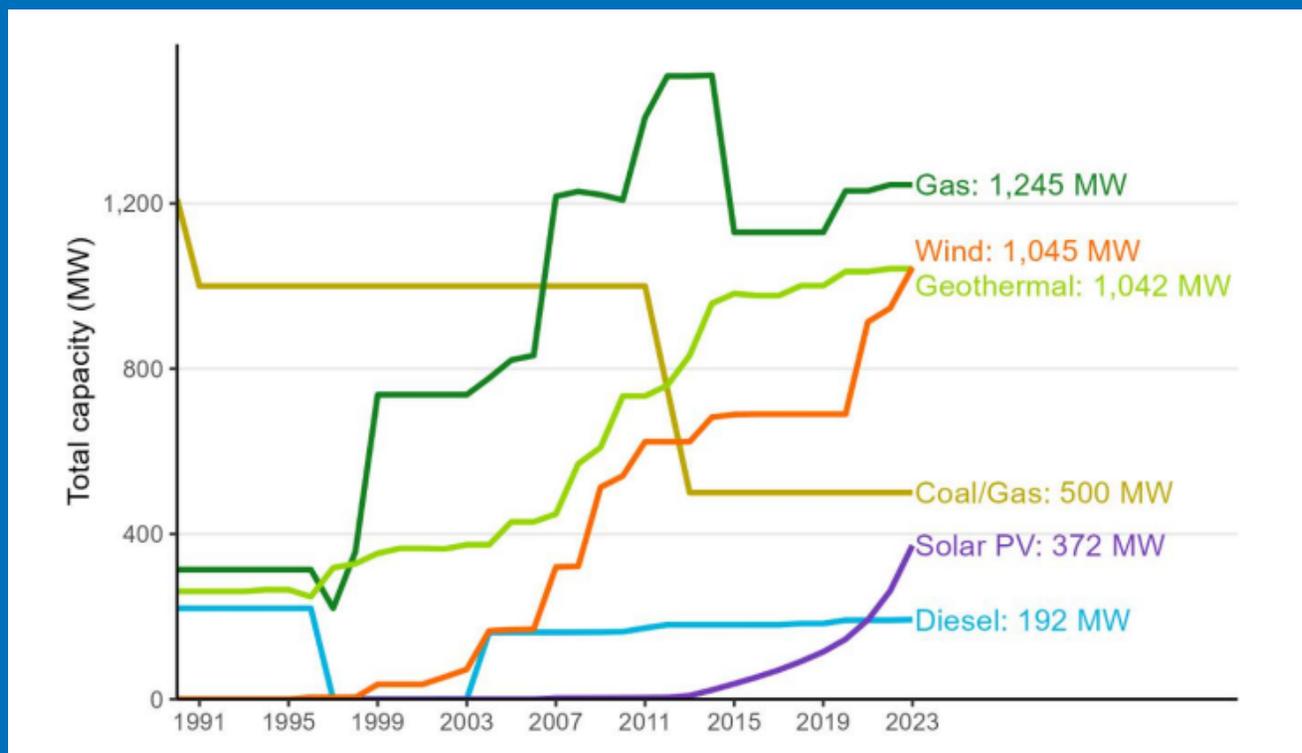
Engineering Tomorrow's Energy Future

Embedded Solar Farm Connection Studies

Josh Burrows

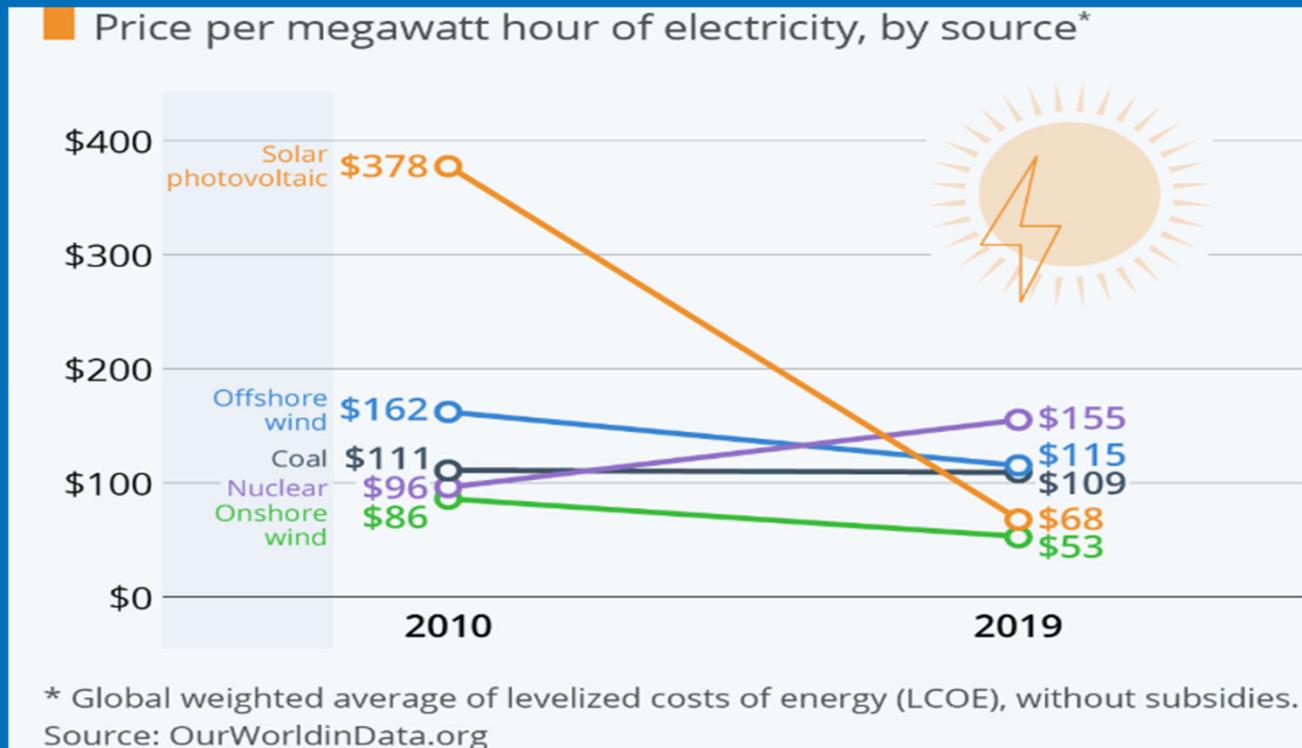


Overview: Solar Generation Trends



(MBIE, Energy in New Zealand 2024)

Overview: Solar Generation Trends



Overview: Connection Studies

- Quantify impact to existing electrical infrastructure
- Generally occurs at feasibility stage

Overview: Dynamic vs. Steady State

Steady State = 'Show stoppers'

Steady-State Power
Flow

Voltage Stability

Short-Circuit Analysis

Protection Coordination

Dynamics = Tuning

Dynamic (Transient)
Stability

Frequency Response

Fault Ride-Through

Overview: Embedded vs. Large Scale Generation

Large Scale Generation

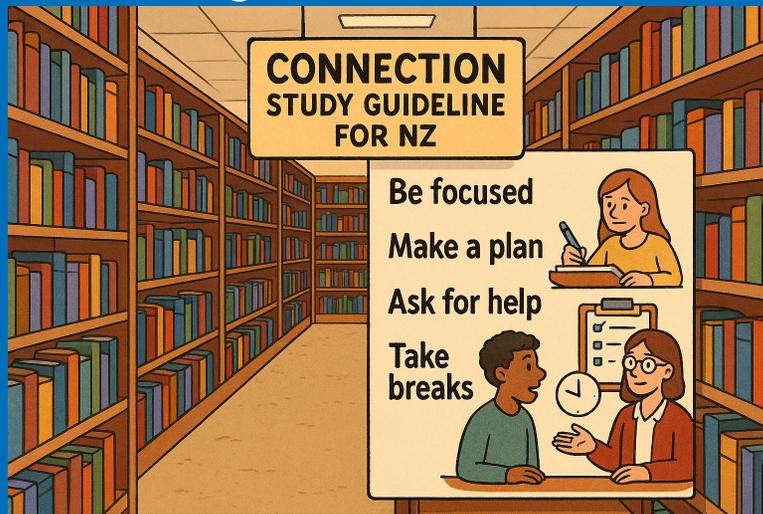


Embedded Generation



Embedded vs. Large Scale Generation Standards

Large Scale Generation



Embedded Generation



Study Considerations

- **Reactive Power Capability**
- **Quasi-Dynamic Load Flow**
- **Short Circuit**

Reactive Power Capability

- Control voltage
- Lesson: Communication!

Reactive Power Capability Standards

Large Scale Generation

8.23 Voltage support AOPOs

Each generator with a point of connection to the grid must at all times ensure that its assets—

- (a) when the voltage at its grid injection point is within the applicable range of nominal voltage, are capable of exporting (over excited) when synchronised and made available for dispatch by the system operator, a minimum net reactive power which is 50% of the maximum continuous MW output power as measured at the following generating unit terminals:

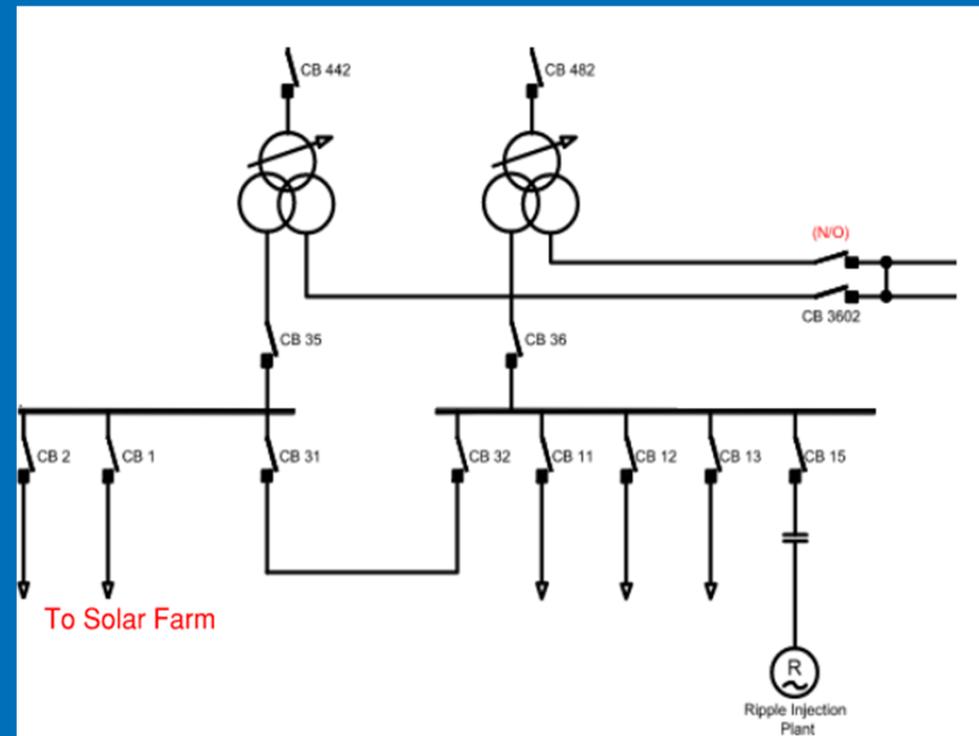
Nominal grid voltage (kV)	Voltage range for which reactive power is required			
	Minimum (kV)		Maximum (kV)	
220	198	-10.0%	242	10.0%
110	99	-10.0%	121	10.0%
66	62.7	-5.0%	69.3	5.0%
50	47.5	-5.0%	52.5	5.0%
33	31.35	-5.0%	34.65	5.0%
22	21.45	-2.5%	22.55	2.5%
11	10.725	-2.5%	11.275	2.5%

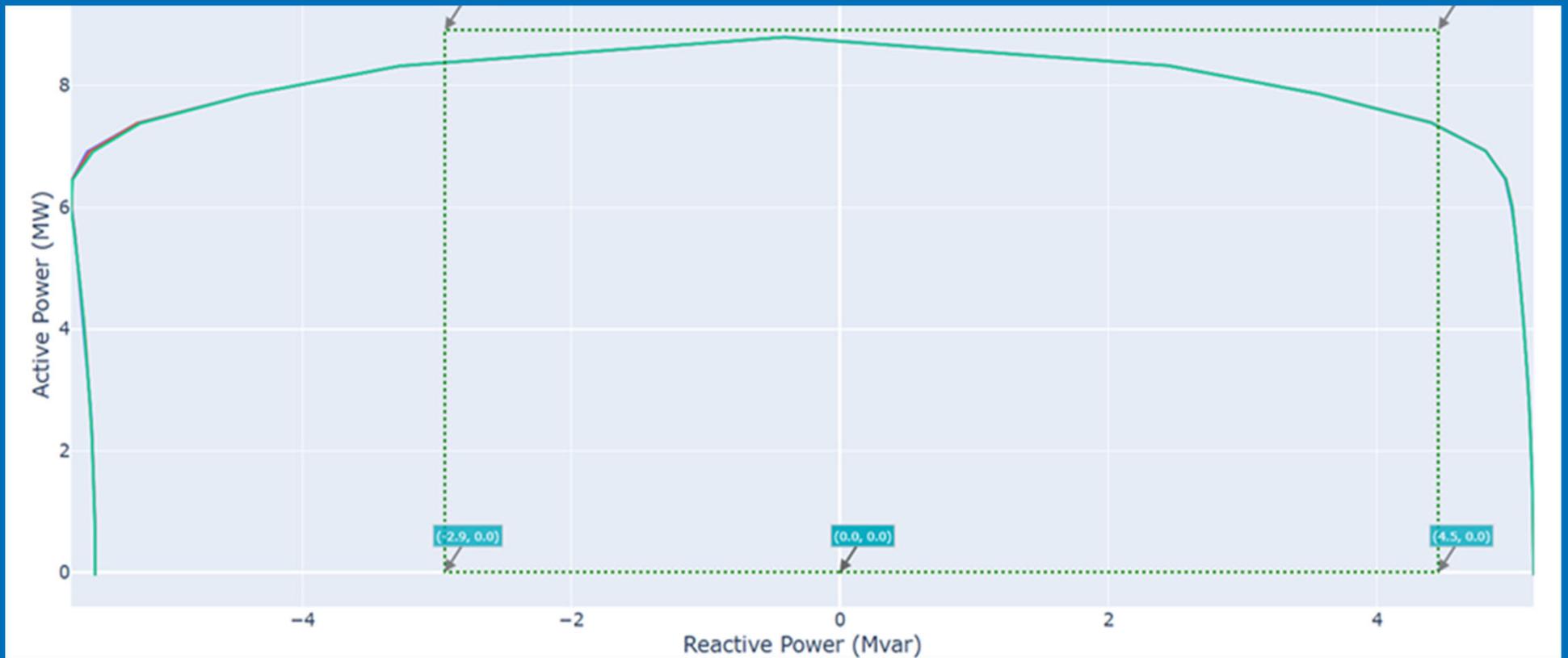
Embedded Generation



Example:

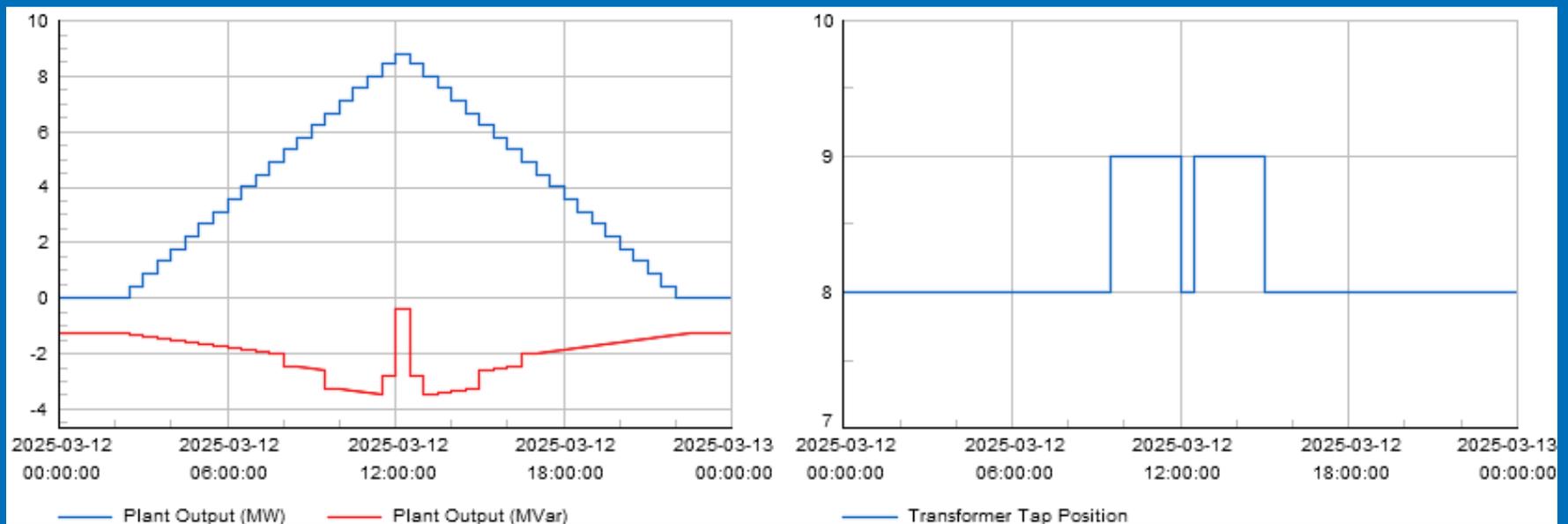
- Adjacent to GXP
- Inverter rating 8.94 MVA
- Developer requested 8.94 MW

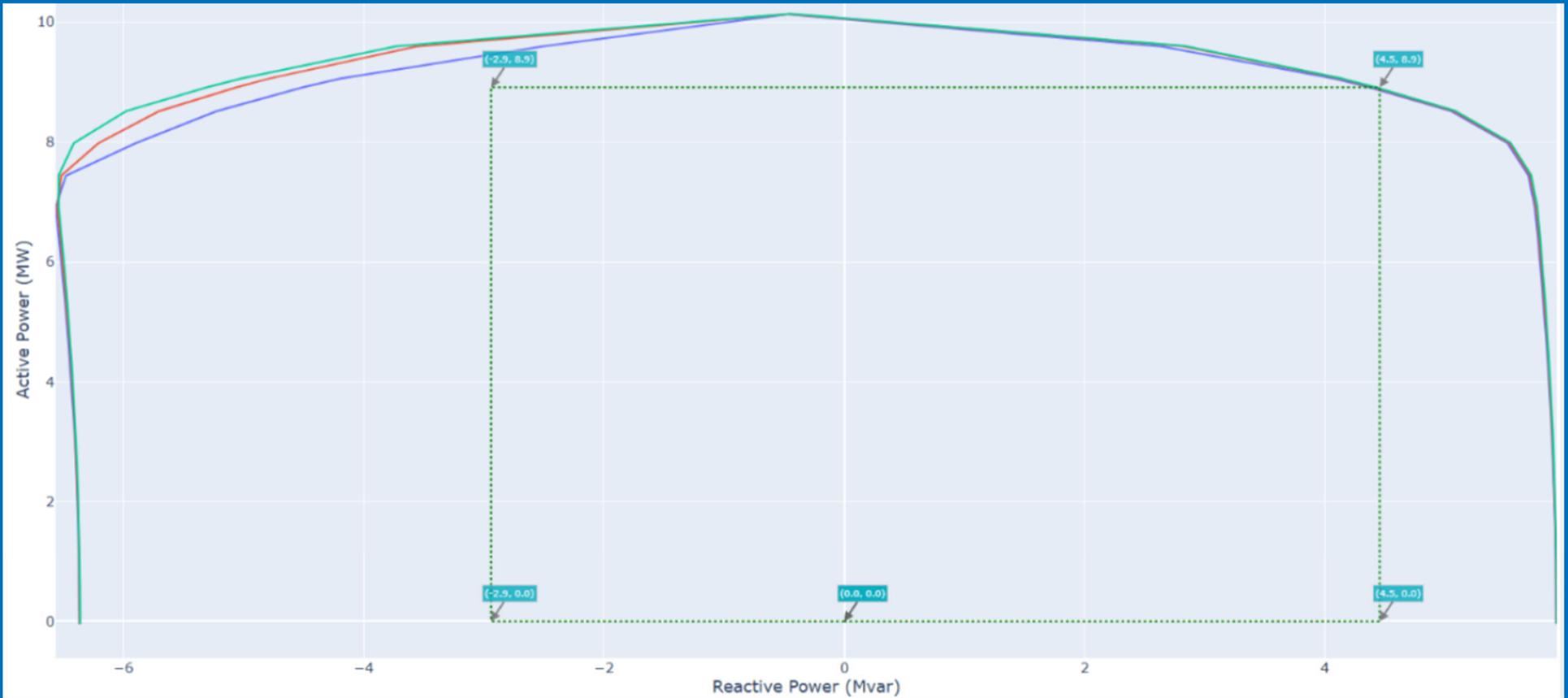




Example:

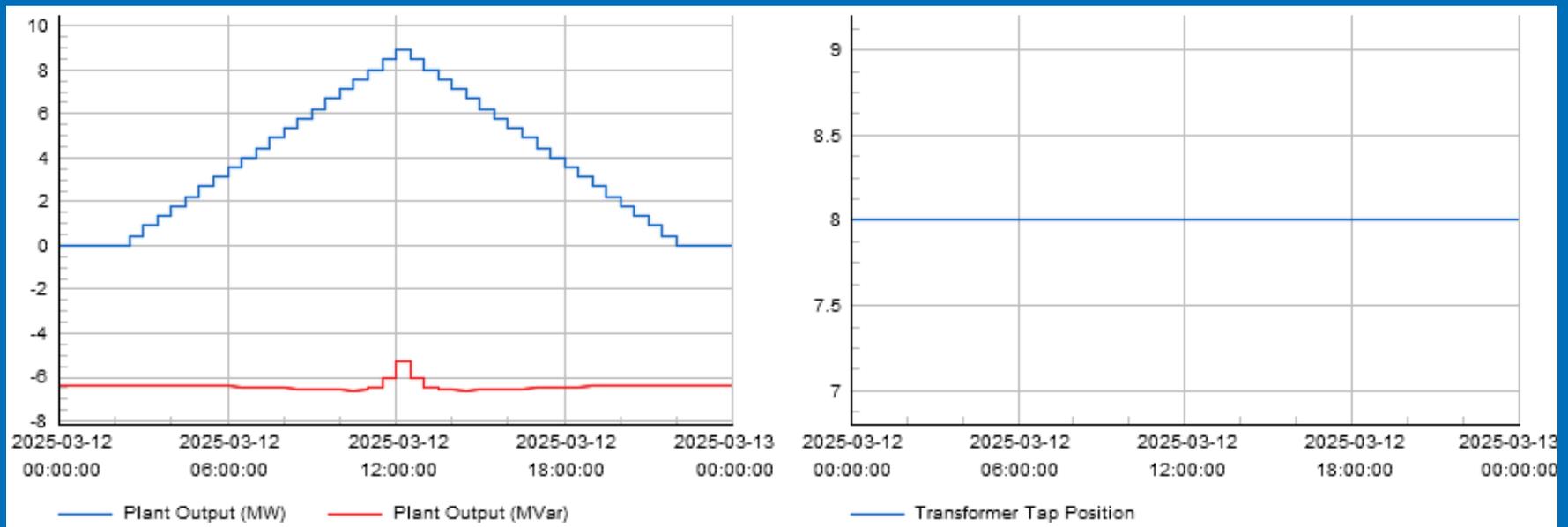
- What about the wider network?





Example:

- More inverters (same MW output)



Quasi-Dynamic Load Flow

- Series of load flows
- Assess reverse power flow risk
- Lesson: Context!

Quasi-Dynamic Connection Standards

Large Scale Generation

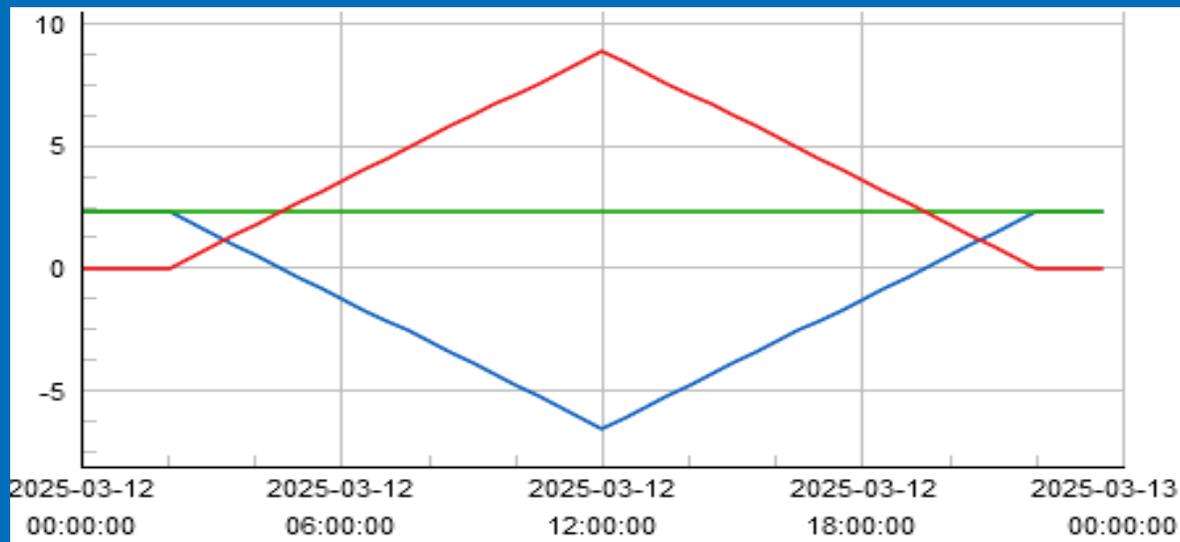


Embedded Generation



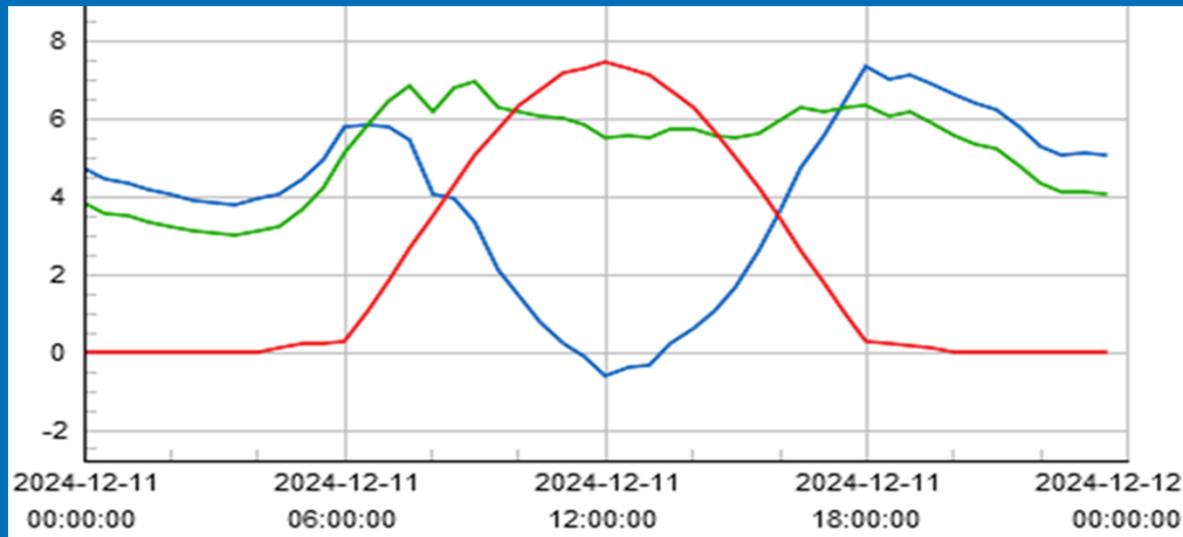
Example 1: Static Loads

- Reverse power flow occurs
- No context (cannot assess risk)



Example 2: Load Profiles

- Reverse power flow occurs
- Context (can assess risk)



Short Circuit

- Determine relative strength of solar farm
- Assess risk of transient behavior
- Lesson: Relative!

System Strength

- Ability to maintain grid voltage (steady state and disturbance)
- Proportional to fault level at location
- Quantified by Short Circuit Ratio (SCR)

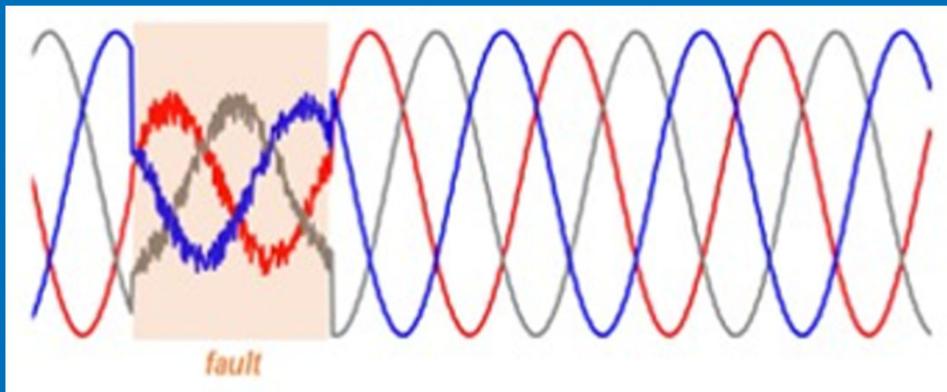
Short Circuit Ratio

$$SCR = \frac{S_{3\phi FL}}{S_{GEN}}$$

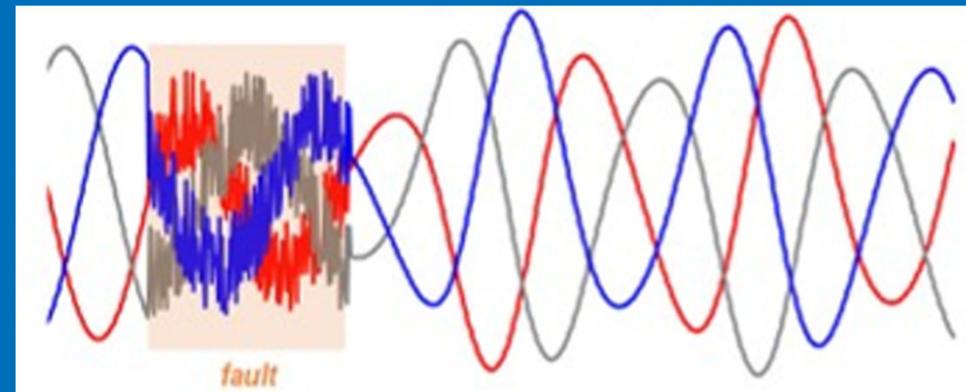
- SCR of >3 is required
- Inverter behavior cannot be guaranteed

Short Circuit

High relative system strength



Low relative System Strength



Summary

- **Embedded connections are increasing rapidly**
- **Communication and collaboration is key**

