Taiwan Power Company Actions under High Renewable Energy Penetration

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Outline

1. Preface
2. About Kinmen Smart Grid
3. MicroGrid Standardization
4. Back to System Level
5. Conclusion

RE Develop and IBR Grow

- As of Nov. 2024:
  - Solar (PV): 13.9 GW
  - Wind: 3.9 GW

Over 25 GW increase in just a few years

- By 2030 (Target):
  - Solar (PV): 30 GW
  - Wind: 13.1 GW

- Most new resources are IBRs (Inverter-Based Resources):
  - PV, wind, and battery energy storage systems (BESS)
  - Fast response, but lack: Rotational inertia, Short-circuit capacity, Reactive power support, Dynamic dispatch capability

RE: Renewable Energy; IBR: Inverter Based Resource; BESS: Battery Energy Storage System

2. About Kinmen Smart Grid

2.1 Kinmen Grid Overview

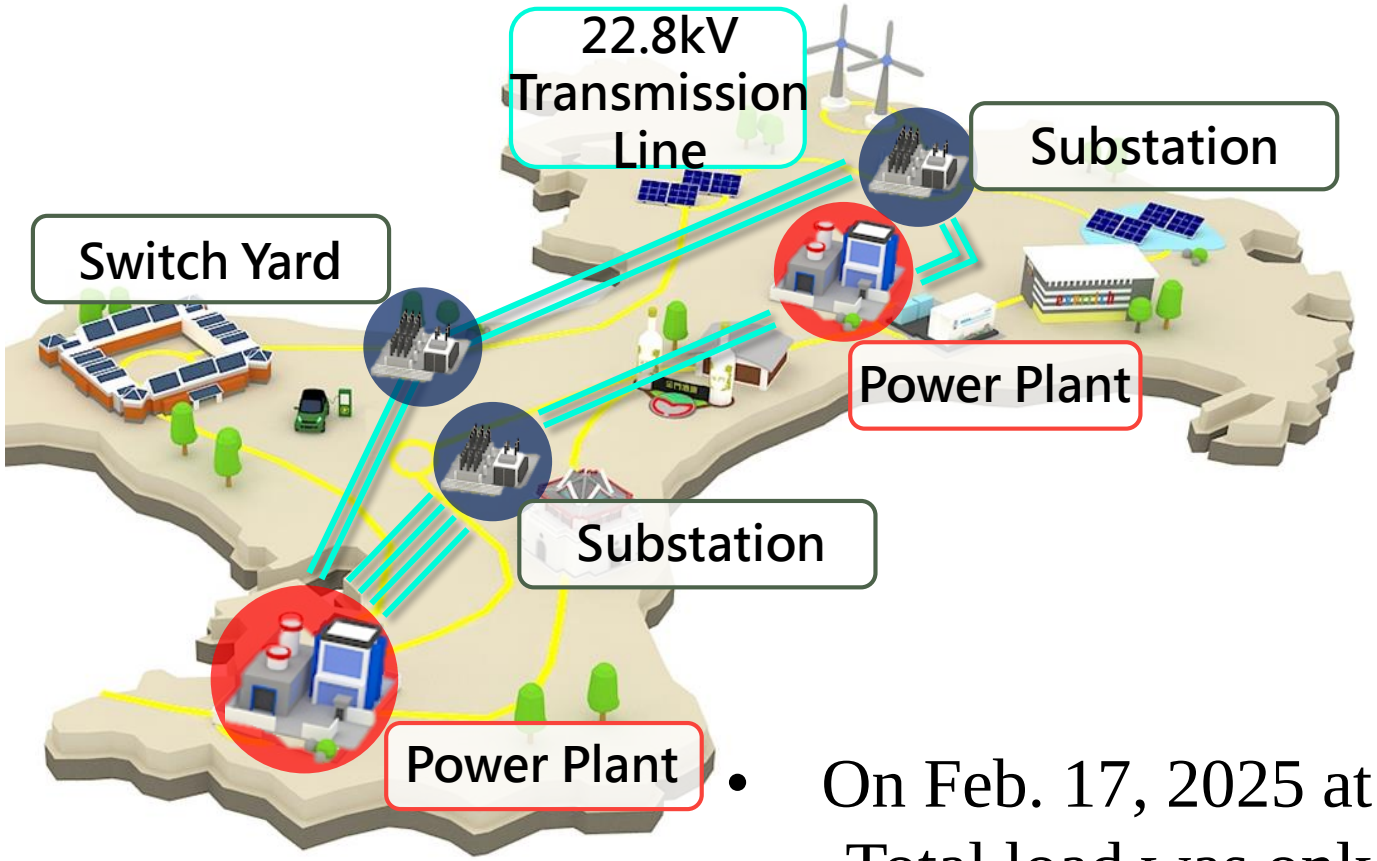
2.2 BESS Project

2.3 Load Shedding Project

2.4 EMS Project

2.5 Communication Infrastructure & Information Security

Kinmen Grid Overview



- Kinmen is an isolated island grid with limited fault tolerance
- Load ranges from 20 MW (early winter morning) to 65 MW (summer noon)
- Total generation capacity: 107.2 MW
  - Including 4 MW wind and 27.5 MW (and growing) from solar PV

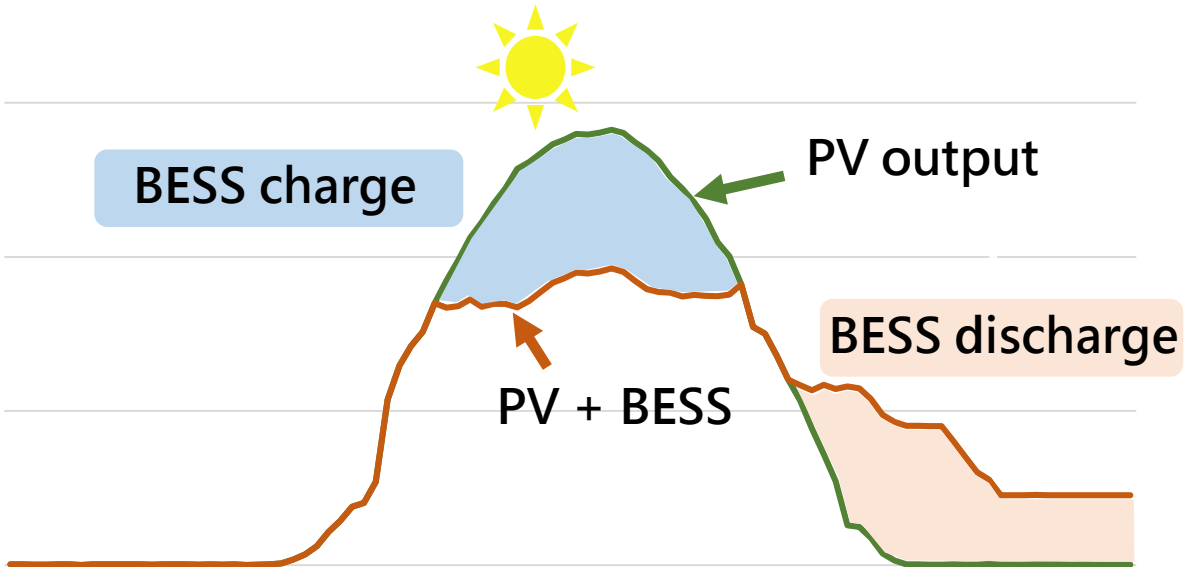
- On Feb. 17, 2025 at noon:
  - Total load was only 34 MW
  - Renewable generation exceeded 20 MW (over 70% of total load)

BESS Project

Long Duration Energy Shifting

Site: Power Plant
Type: NAS
Power: 1.8MW
Capacity: 10.8MWh

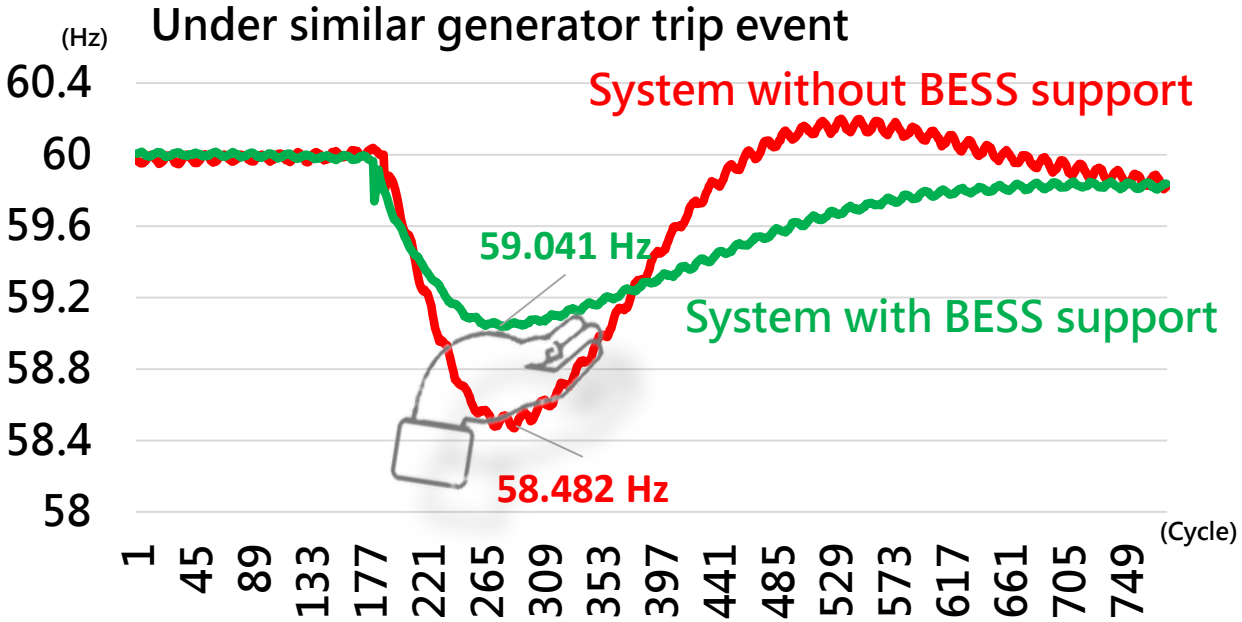
Site: Switch Yard
Type: Li-ion
Power: 6.4MW
Capacity: 26.1MWh



Short Duration Frequency regulation

Site: Power Plant
Type: Li-ion
Power: 2MW
Capacity: 1MWh

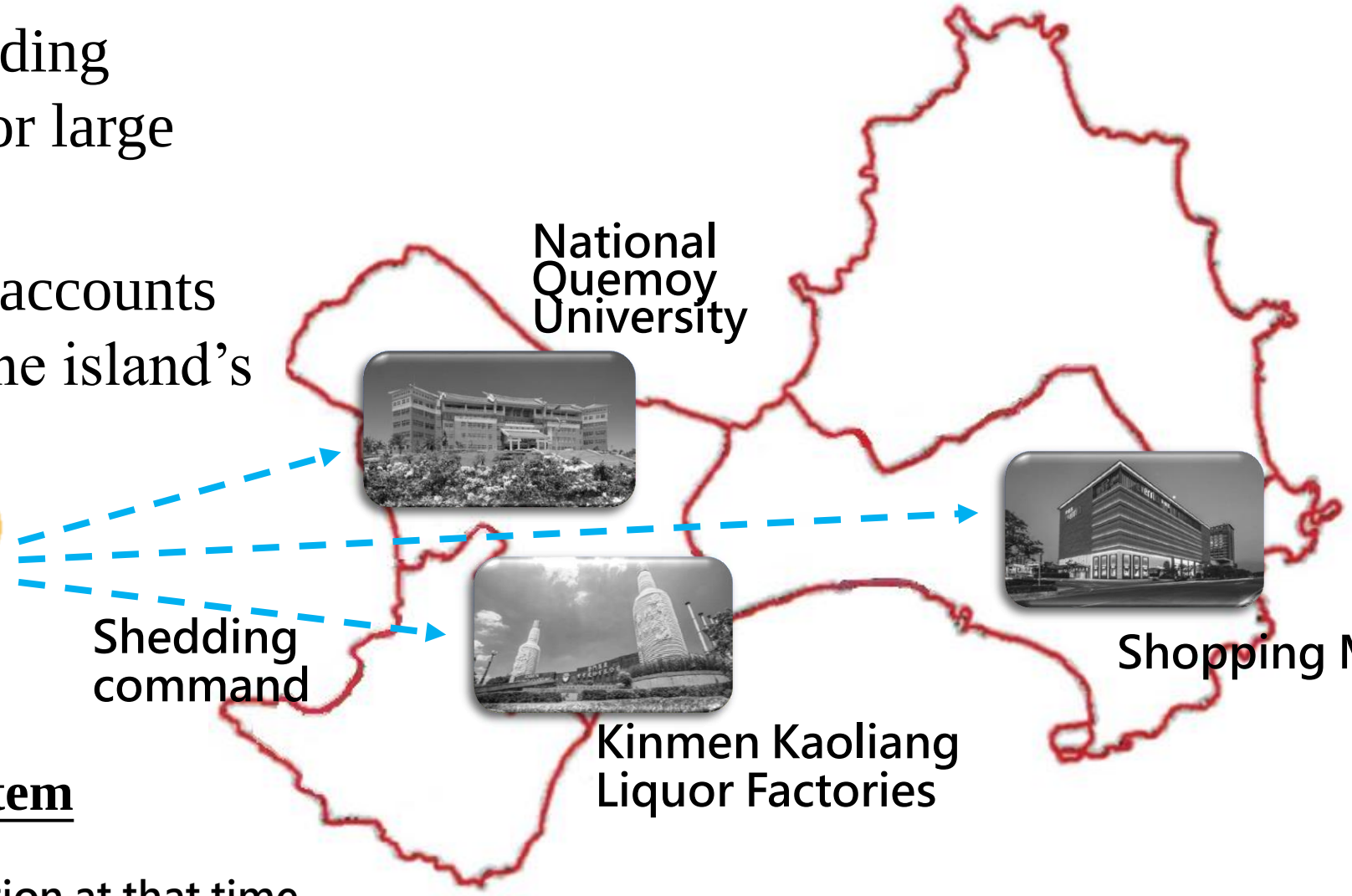
Site: Switch Yard
Type: Li-ion
Power: 2.1MW
Capacity: 3.2MWh



Load Shedding Project

- Voluntary load-shedding program launched for large users
- total shed-able load accounts for around 28% of the island's residential demand

Special Protection System



*Calculated based on the situation at that time

EMS Project

Forecast

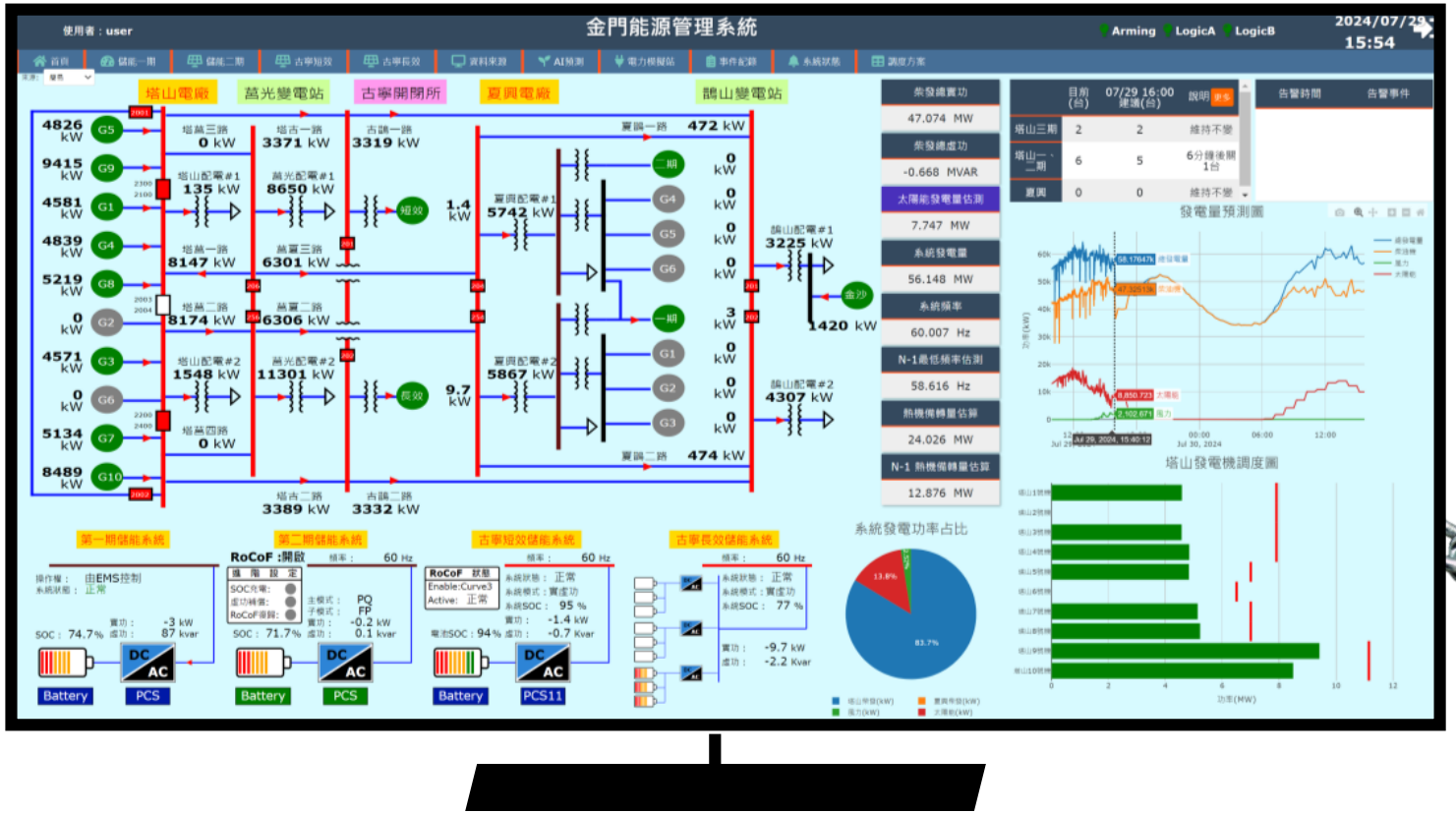
- both load and renewable generation

Historical Data

- For load prediction

Real time info.

- **Gen. status**
- **BESS status**
- System topology and Power flow
- **G-1 frequency prediction**
- Spinning reserve



BESS control

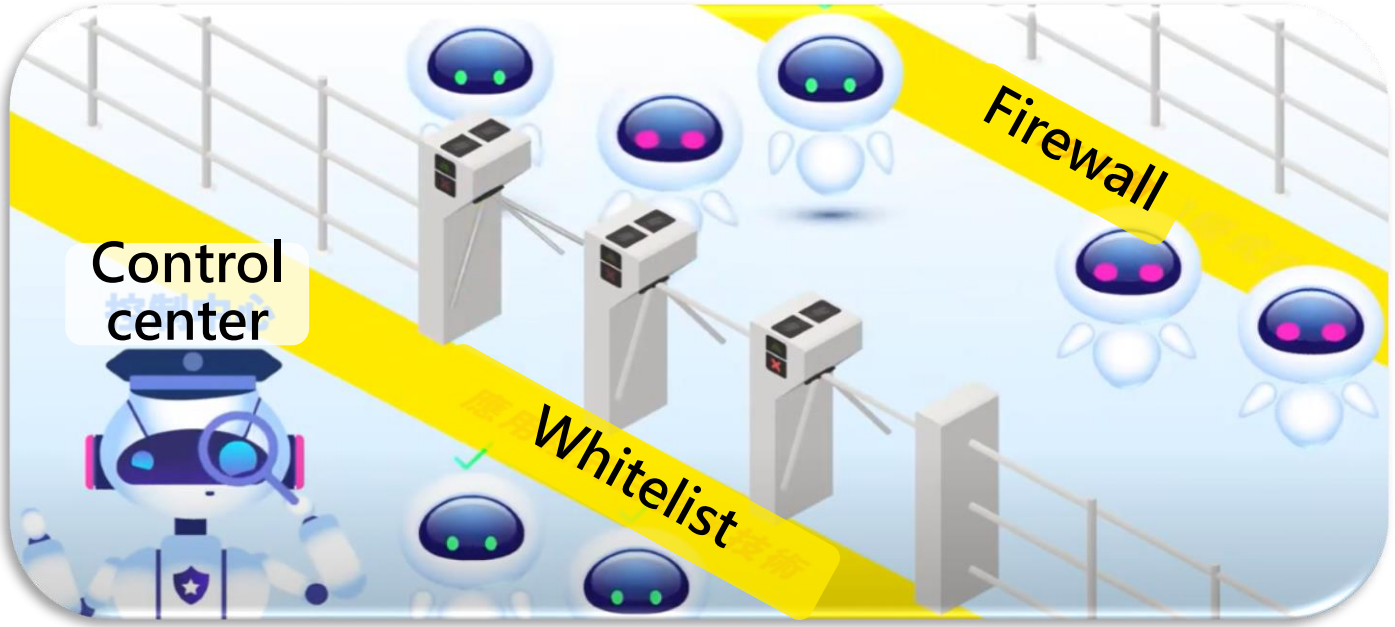
- Control mode
- PQ setpoint

Simulation

- using a PSSE-linked interface

Communication Infrastructure & Information Security

- Island-wide fiber optic network deployed to connect EMS, batteries, and automated switches
- Three-layer cybersecurity defense: firewall, application whitelisting, and centralized monitoring via security control center



3. MicroGrid(MG) Standardization

3.1 MG types

3.2 Su-Lin campus MG Resources

3.3 Su-Lin campus MG Functions

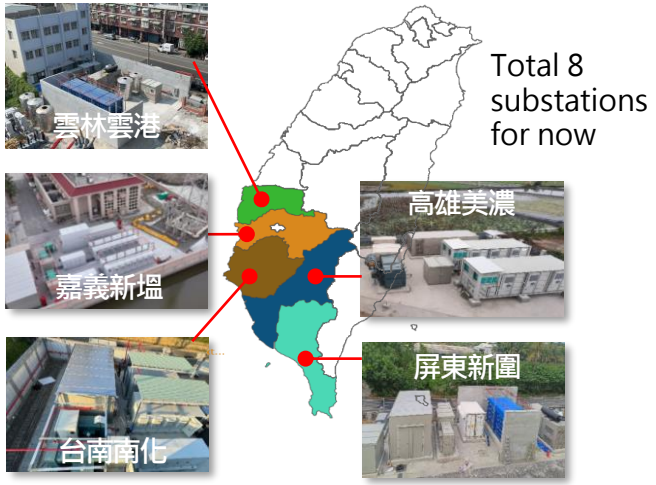
3.4 MG Verification Integration Platform

MG types

Site: Fushan Village
Purpose: Disaster prevention type

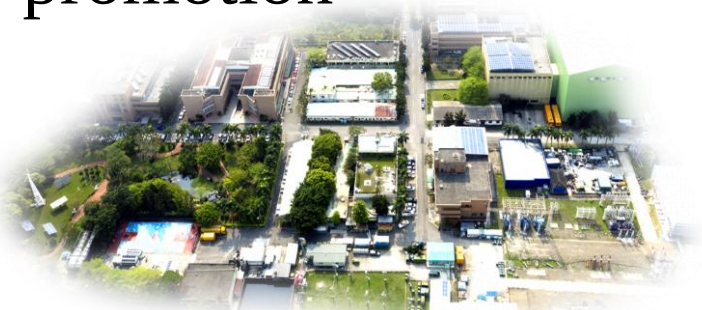
Main Functions：
- Islanding operation
- DER management

Site: Substations
Purpose: System Resilience



Main Functions：
- Islanding operation
- DER management
- Ancillary Service

Site: Su-Lin campus
Purpose: Function display & Standardize promotion



Main Functions：
- Seamless Islanding operation
- Optimize operation
- **Join Energy Trading Platform**

DER: Distribution Energy Resource

Su-Lin campus MG Resources

Relay and PMU

PMU - IEEE C37.118 GOOSE

1MW/1.5MWh
GFM BESS

Modbus

500KW/1230kWh
GFL BESSs

Modbus

125kW/40kWh
Nanogrid BESS

Modbus

MGCS*

848KW
PV

Modbus

1MW/6MWh
GFM BESS

Modbus

Under construction

210KW
Fuel Cell

Modbus

Under construction

500kW
Diesel Gen.

Modbus

Under construction

MGCS: Micro-Grid Control System

GFM(L): Grid Forming(Following)

Su-Lin campus MG Functions

TPC DERMS or ADMS

Distribution Dispatch Control Center

Receive real time command

DNP3.0 or IEC61850

Load & PV Forecast System

WEB API

TPRI VPP

Modbus

MMS

- Regulation Reserve(sReg)
- Spinning Reserve

MGCS

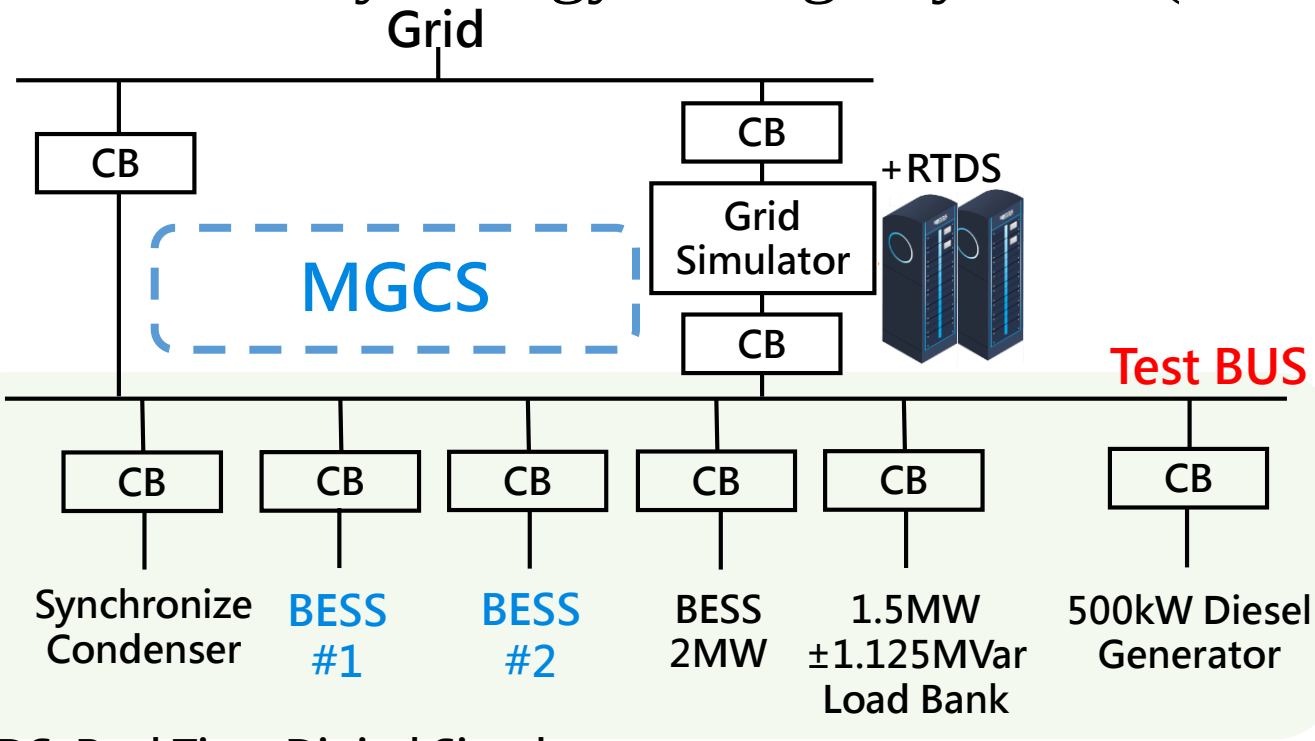
Energy Management:
- Low-carbon optimization
- Revenue optimization

Status Transition:
- Grid tie -> Islanding
- Black start
- Islanding -> Grid tie

VPP: Virtual Power Plant

MG Verification Integration Platform

- Established in Shulin based on IEEE 2030.8 to verify system performance before field deployment
- Allows testing of key components—such as Microgrid Controllers (MGCS) and Battery Energy Storage Systems (BESS)—under simulated grid conditions



RTDS: Real Time Digital Simulator

4. Back to System Level

4.1 Resource Dispatching

4.2 BESS Operation

4.3 Inertia Monitoring

4.4 Voltage Control

4.5 PV Reactive Power Control at Night

4.6 IBR Ride Through Capability

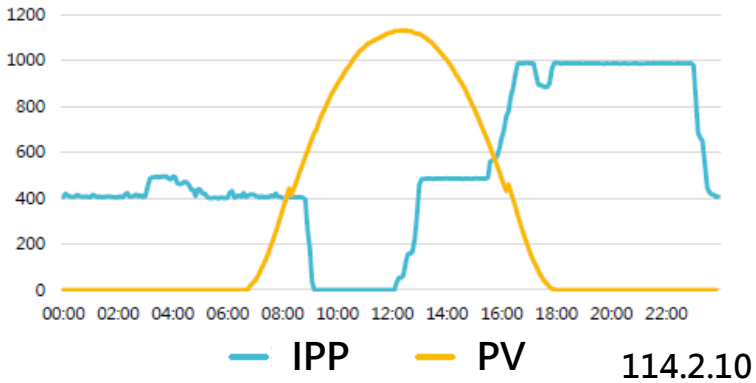
4.7 Resolve Congestion

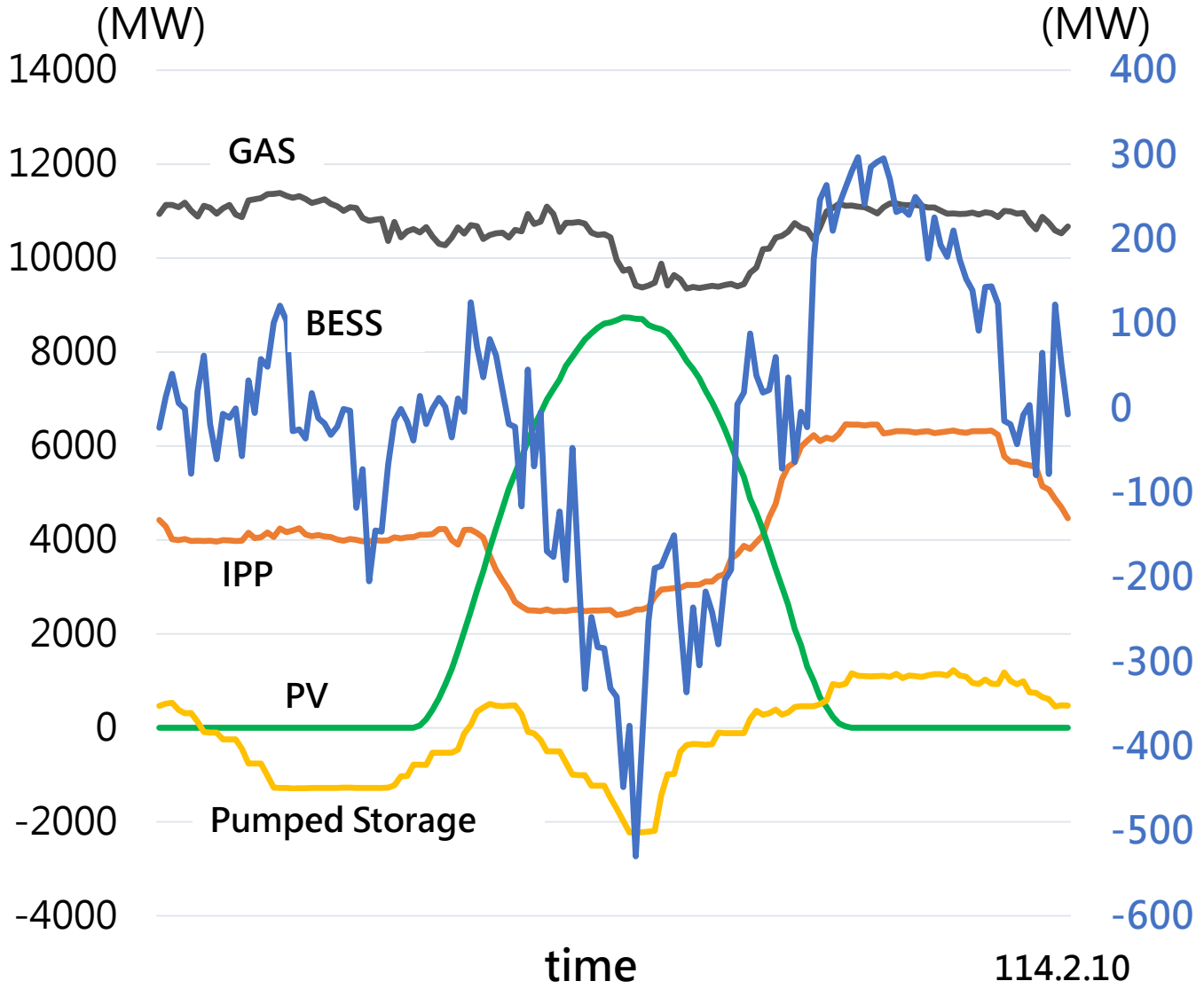
4.8 RE Curtailment

4.9 Synchronous Condenser

Resource Dispatching

- Dispatch coordination across system-wide and regional levels
- Use pumped storage and BESS charging to absorb excess solar generation
- Ramp down thermal units and curtail local IPPs in congested areas to prioritize renewable energy





IPP: Independent Power Producer

BESS Operation

- dReg：Frequency control
- E-dReg：
  - Frequency control
  - Energy shifting
  - Pause Energy shifting when freq. under 59.5Hz
- PV+BESS：
  - Energy shifting
  - Discharge by rated power when freq. under 59.5Hz

Inertia Monitoring

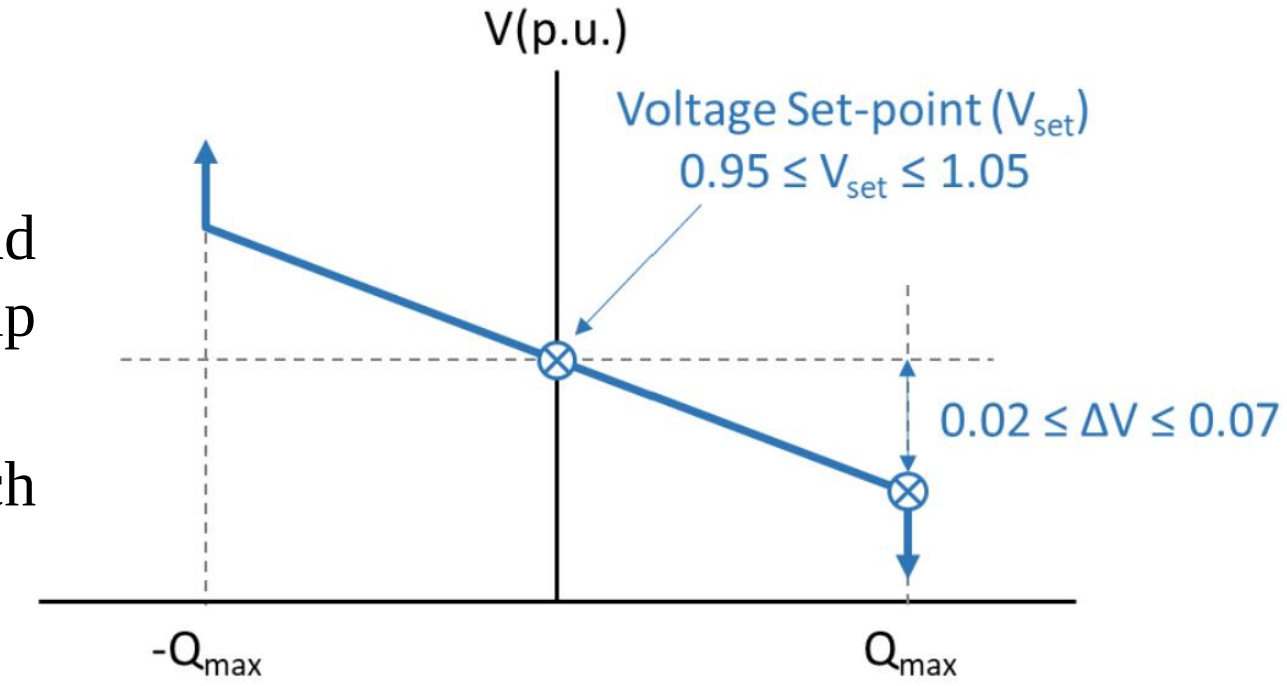
- Inverter-based resources lack inertia, creating new operational challenges
- Real-time inertia monitoring system uses BESS to inject disturbances and measure frequency response

電力心電圖 台電導入「即時慣量測量系統」強韌電網

Voltage Control

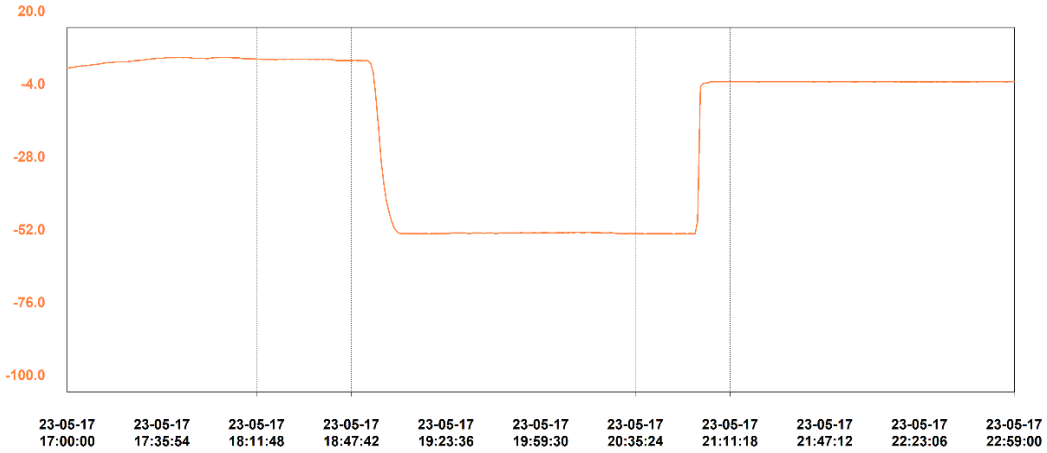
- Updated technical requirements for RE interconnection to ensure basic reactive power control
- RE systems at 69 kV and above must support: (1) V-Q control, (2) constant Q, and (3) constant PF modes
- Grid codes for BESS are being revised to include reactive power support

- In high-PV areas, shunt reactors and transmission line switching help manage voltage
- STATCOMs deployed in wind-rich regions to enhance voltage stability

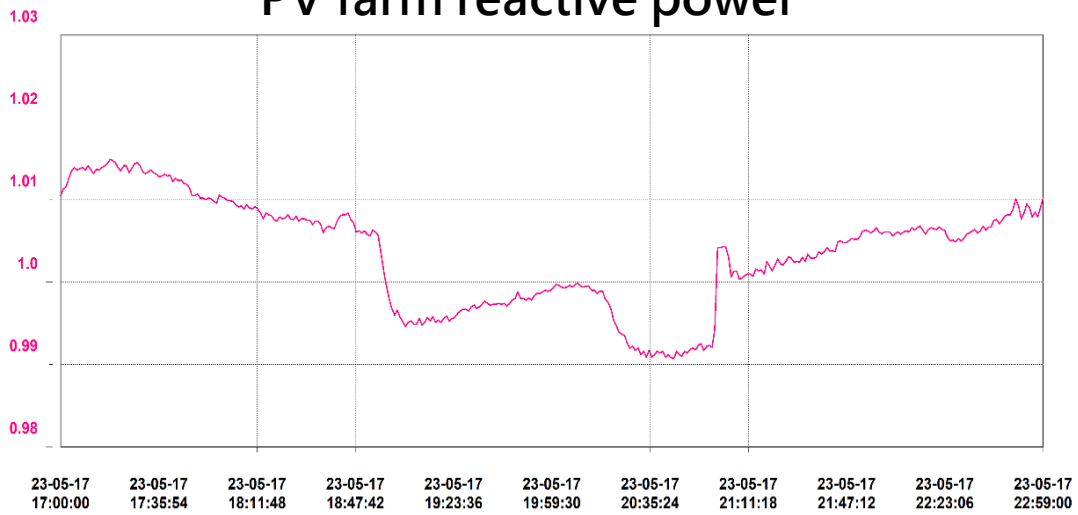


PV Reactive Power Control at Night

- Trial at Tainan Salt Pan PV Farm showed nighttime absorption of ~48 MVAR, lowering 161 kV bus voltage by 1.9 kV
- Demonstrates potential for PV inverters to support voltage at night, with proper coordination



PV farm reactive power

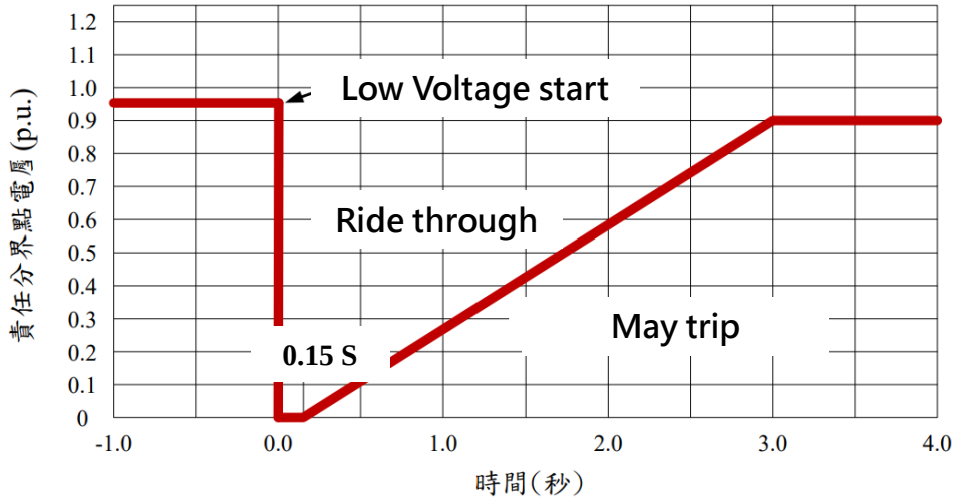


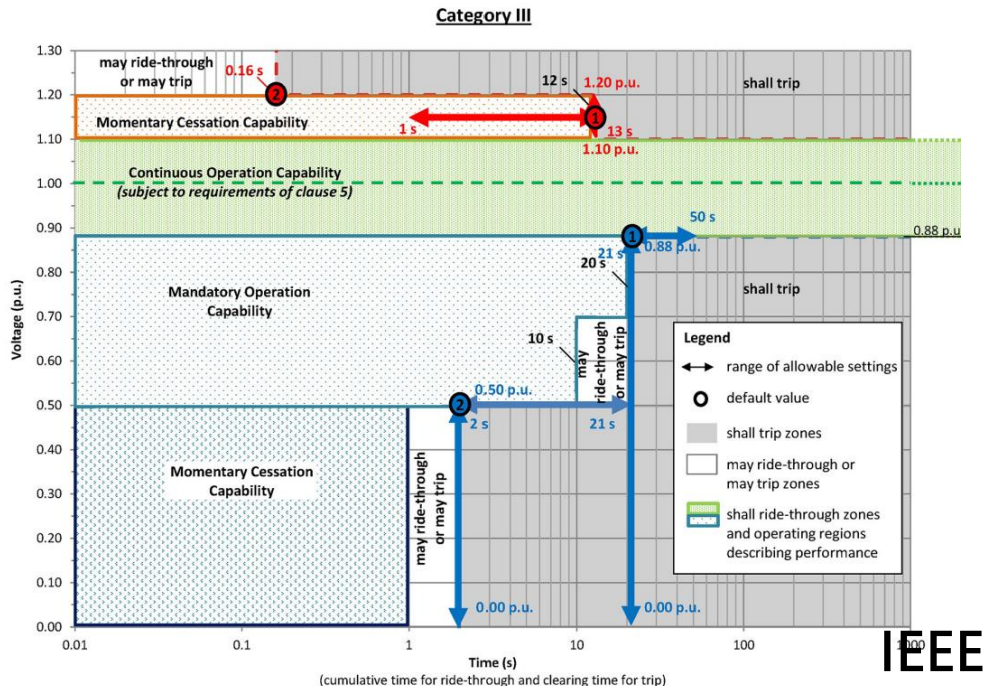
161kV BUS voltage

IBR Ride Through Capability

- Current rule requires RE systems connected at 69 kV and above to have LVRT capability
- As RE penetration increases, ride-through requirements are being strengthened to prevent widespread inverter tripping
- New grid codes—based on IEEE 1547—will extend LVRT to lower voltage levels

RE interconnection technical requirement



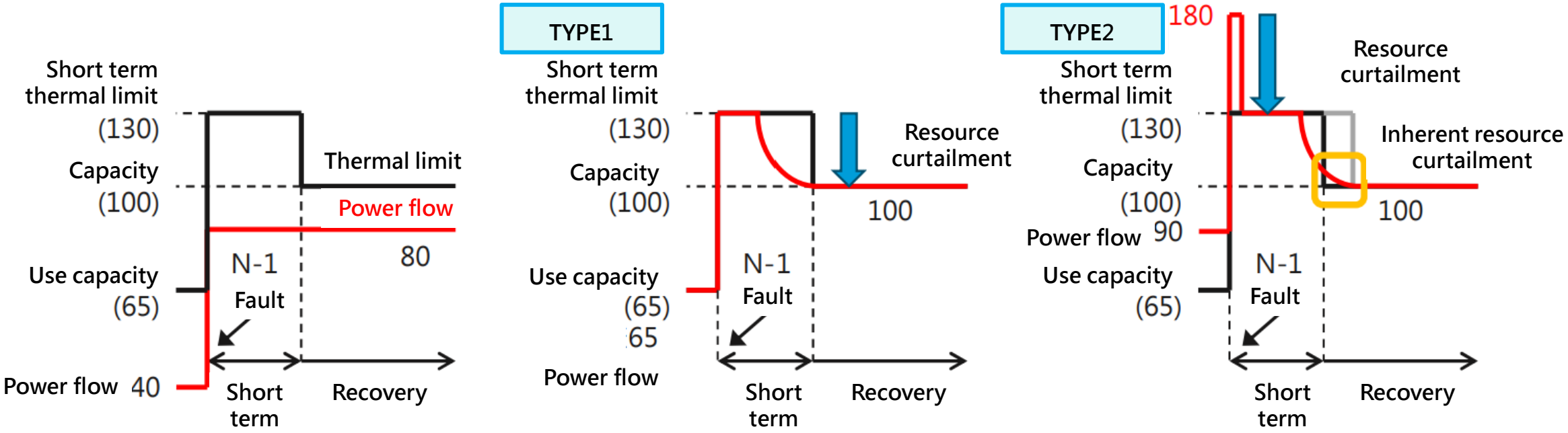


LVRT: Low Voltage Ride Through

IEEE 1547

Resolve Congestion(JAPAN)

- Apply flexible curtailment strategies to manage grid congestion
- Allow higher RE integration under normal conditions, curtail only during N-1 contingencies
- Improve grid utilization while staying within operational limits



RE Curtailment(JAPAN)

- Execute RE curtailment when needed to manage congestion or maintain inertia
- Use multiple approaches: scheduled curtailment, real-time dispatch, and telecom notifications by voltage level

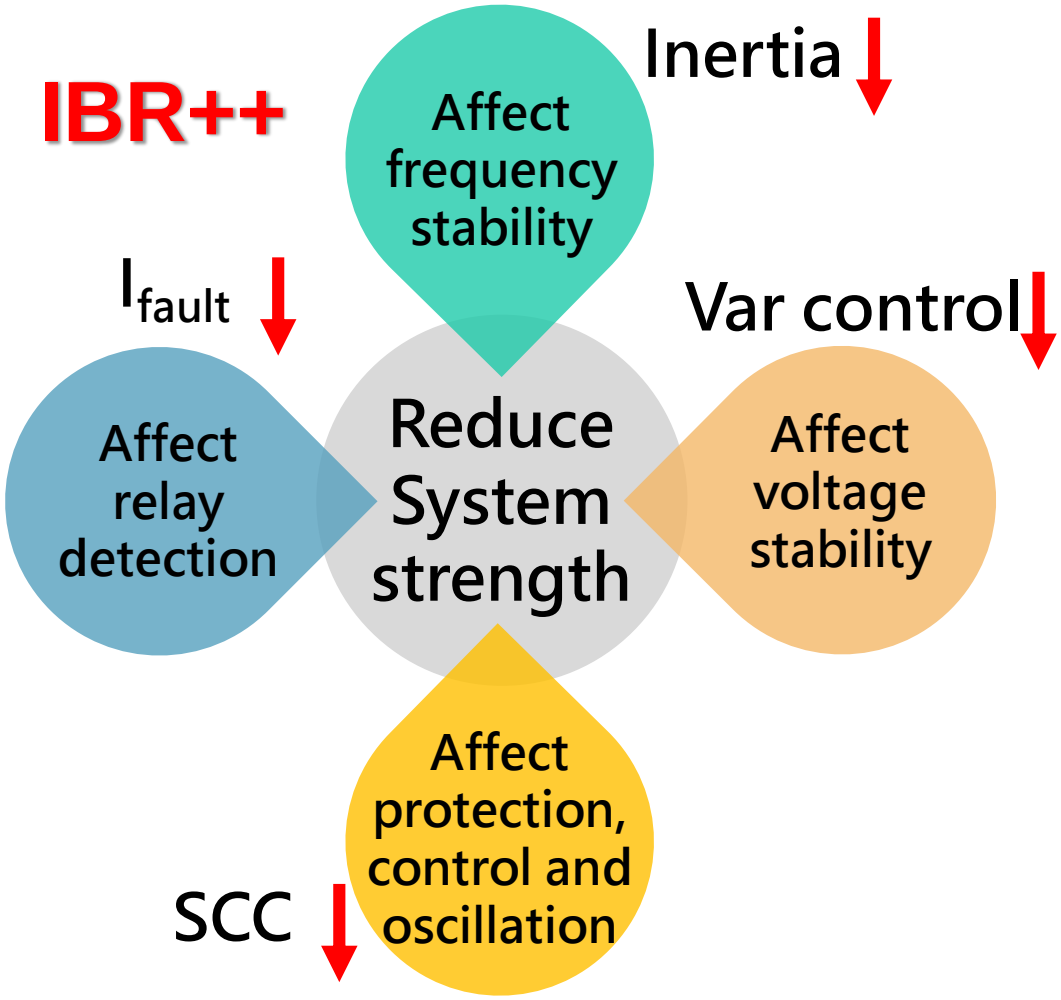
TPC is discussing technical requirement and mechanism for RE curtailment

RE curtailment with no compensation

Contract Acceptance Date	~2015/1/25	2015/1/26~ 2021/3/31	2021/4/1~
PV	30 days / year	360 hours / year	No limitation
WIND	30 days / year Only for 500kW+ site	360 hours / year	No limitation

Synchronous Condenser(Australia)

- As IBR share increases, low short-circuit ratio (SCR) impacts both protection and inverter stability
- Solutions include keeping synchronous generators online, adjusting network topology, and adding synchronous condensers
- Australia has installed over 2,600 MVA of synchronous condensers



TPRI is testing a 5 MVA demo unit to assess its effectiveness

*SC(C)R, Short Circuit (Capacity) Ratio = SCC_{3ph} / $IBR_{rated\ power}$

Conclusion

- Renewable energy is key to achieving Taiwan's net-zero and green energy goals
- Taipower adopts a wide range of strategies—from microgrid pilots to system-level measures—to ensure grid stability
- Step by step, we are building a more flexible, resilient, and intelligent grid to support the energy transition

Thanks for Your Attention