Introduction of Taipower Regional Power Grid Battery Storage Project

Yu-Hsuan Tai
Green Energy Section,
Department of Power Distribution
Taiwan Power Company

Outline

PART 1- Introduction of Project

PART 2- Technical Challenges

PART 3- Islanding Mode Test Results

PART 1

Introduction of Project

The change for Power System in Taiwan

2024 peak load

Total 41.42GW

Northern Part

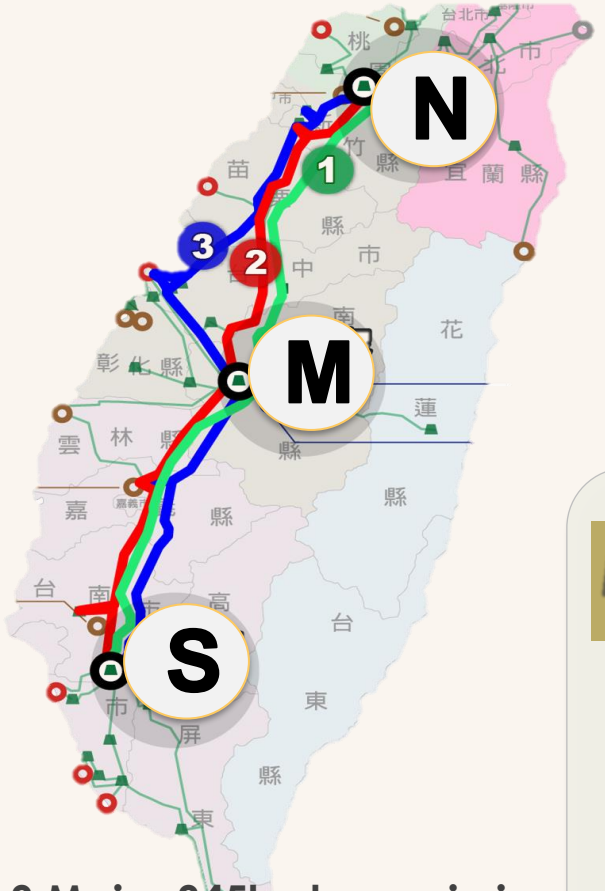
38%

Middle Part

32%

Southern Part

30%



- 3 Major 345kv transmission lines as the back-bone
- 3 Crucial Extra-high Voltage Substations

Past

"Centralized" and "Consolidated" grid to improve efficiency

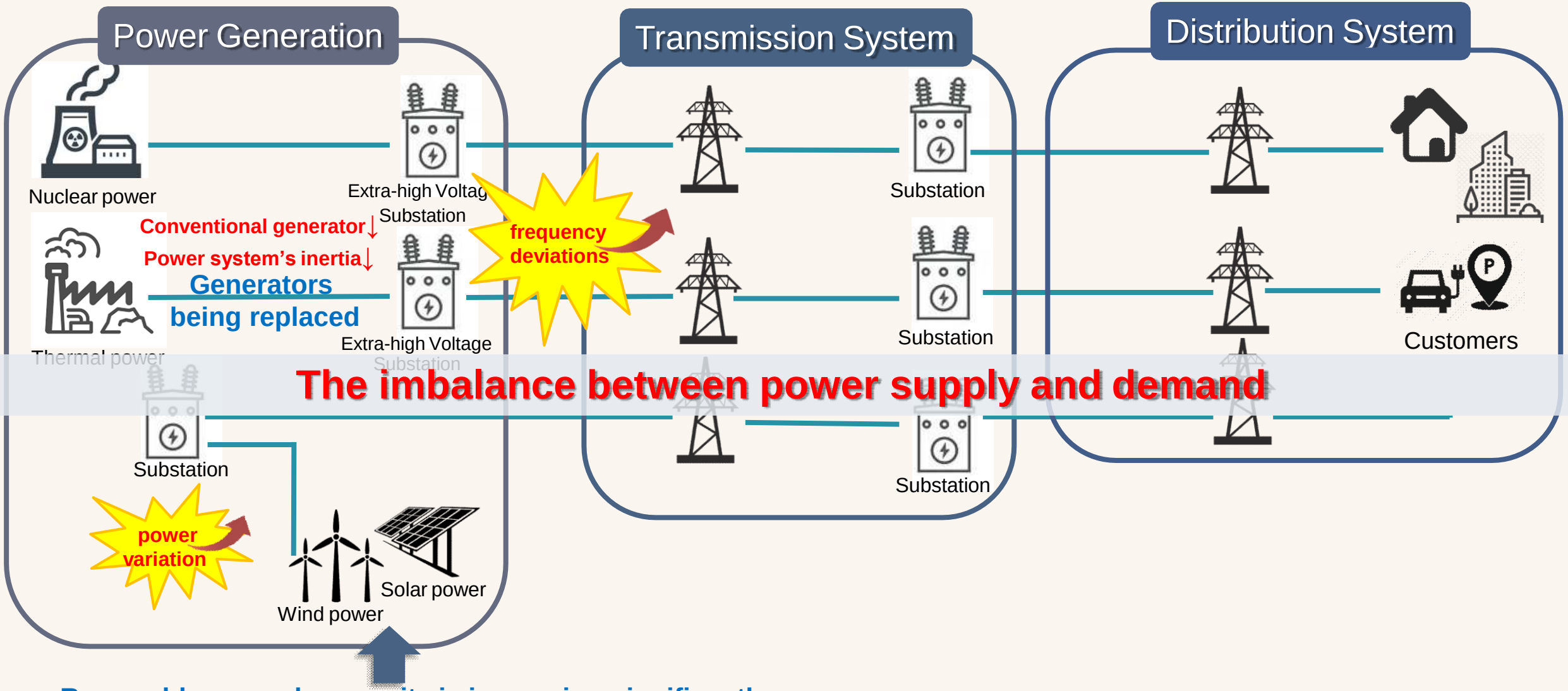
March 3, 2022 Power outage: 5.5million household affected.

Future

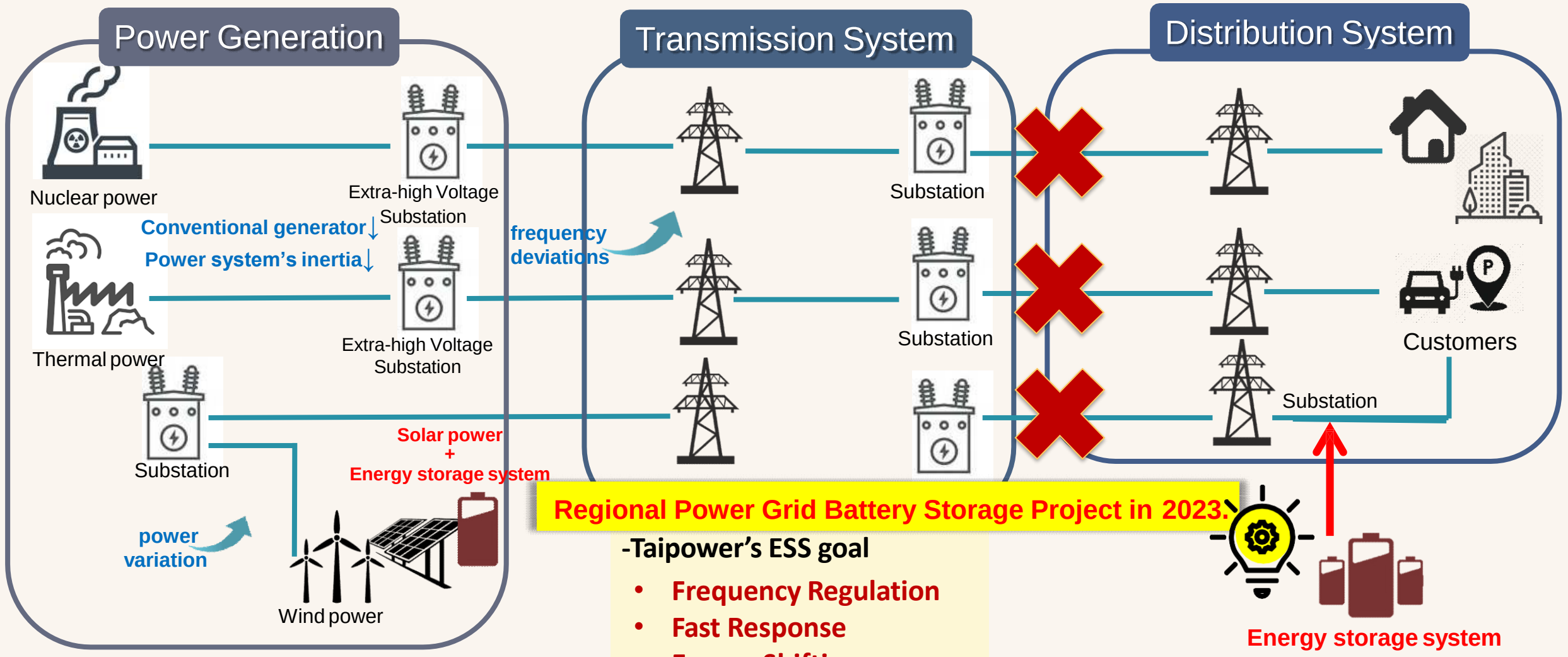
"Divided" and "Dispersed" but interconnected gird to

1. enhance resilience
2. Improve infrastructure
3. More Redundancy
4. Microgrid
5. Black start

Initial conception of the project



Initial conception of the project

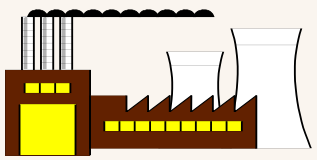


Regional Power Grid Battery Storage Project in 2023.

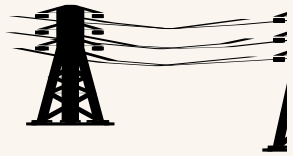
-Taipower's ESS goal

- **Frequency Regulation**
- **Fast Response**
- **Energy Shifting**
- **Feeder Islanding**

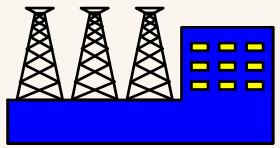
TaiPower's hierarchical dispatch control system



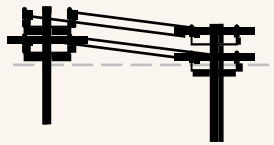
GENERATION



TRANSMISSION



SUBSTATION



DISTRIBUTION

CONSUMER

Central Dispatch and Control Center **(CDCC)**

Area Dispatch and Control Center **(ADCC)**

Distribution Dispatch and Control Center **(DDCC)**

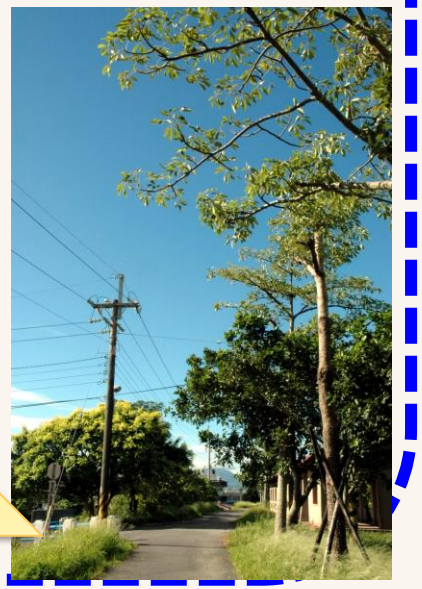
Feeder Dispatch and Control Center **(FDCC)**

1. Second Substation

- 3ϕ4w 11.4kV, 22.8kV

2. Residential / industrial load

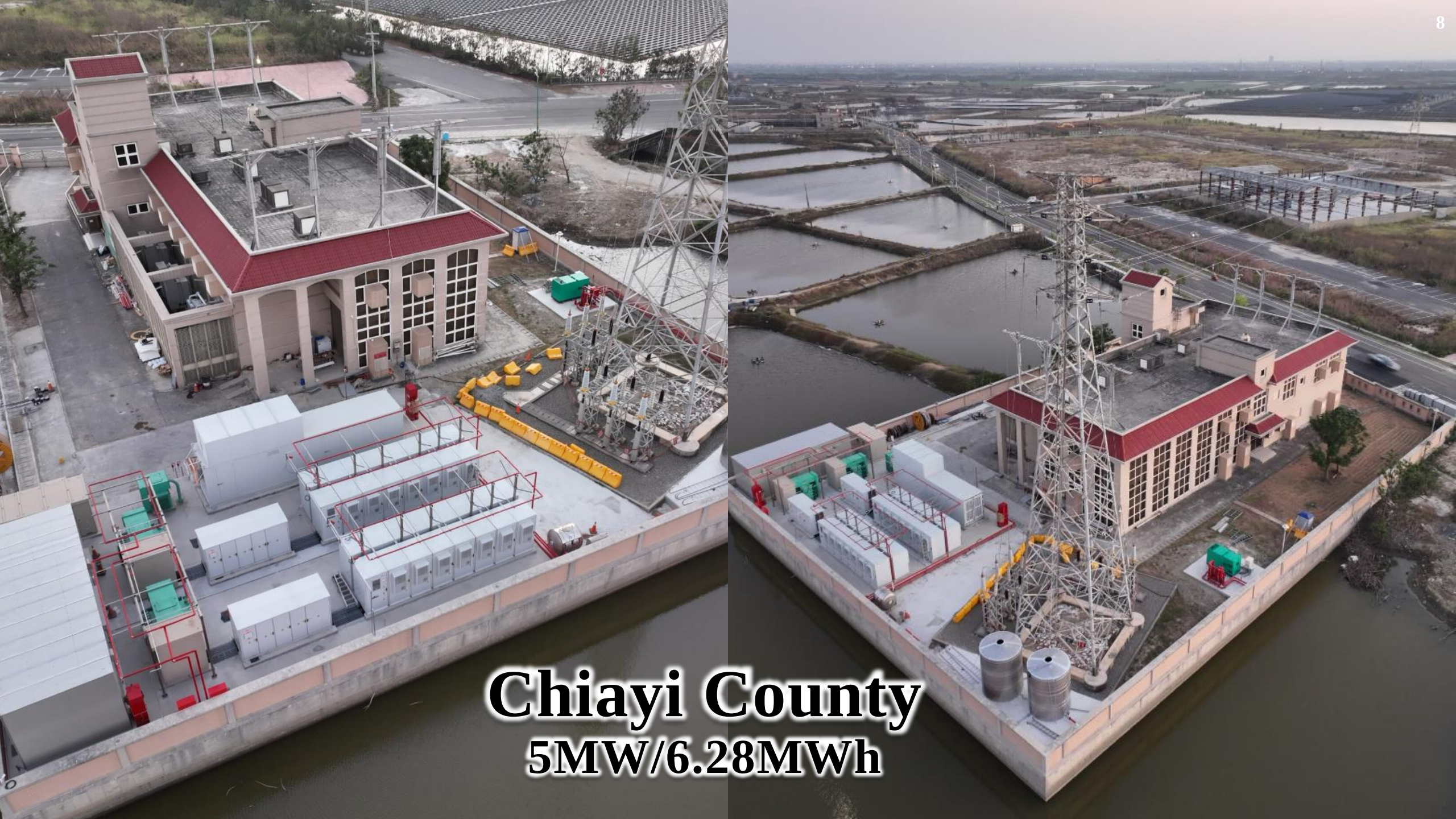
- 1ϕ2w 110V
- 1ϕ2w 220V
- 1ϕ3w 110V/220V
- 3ϕ3w 220V
- 3ϕ4w 220/380V



Regional Power Grid Battery Storage Project Application

Demonstration sites (in 11.4kV distribution system)

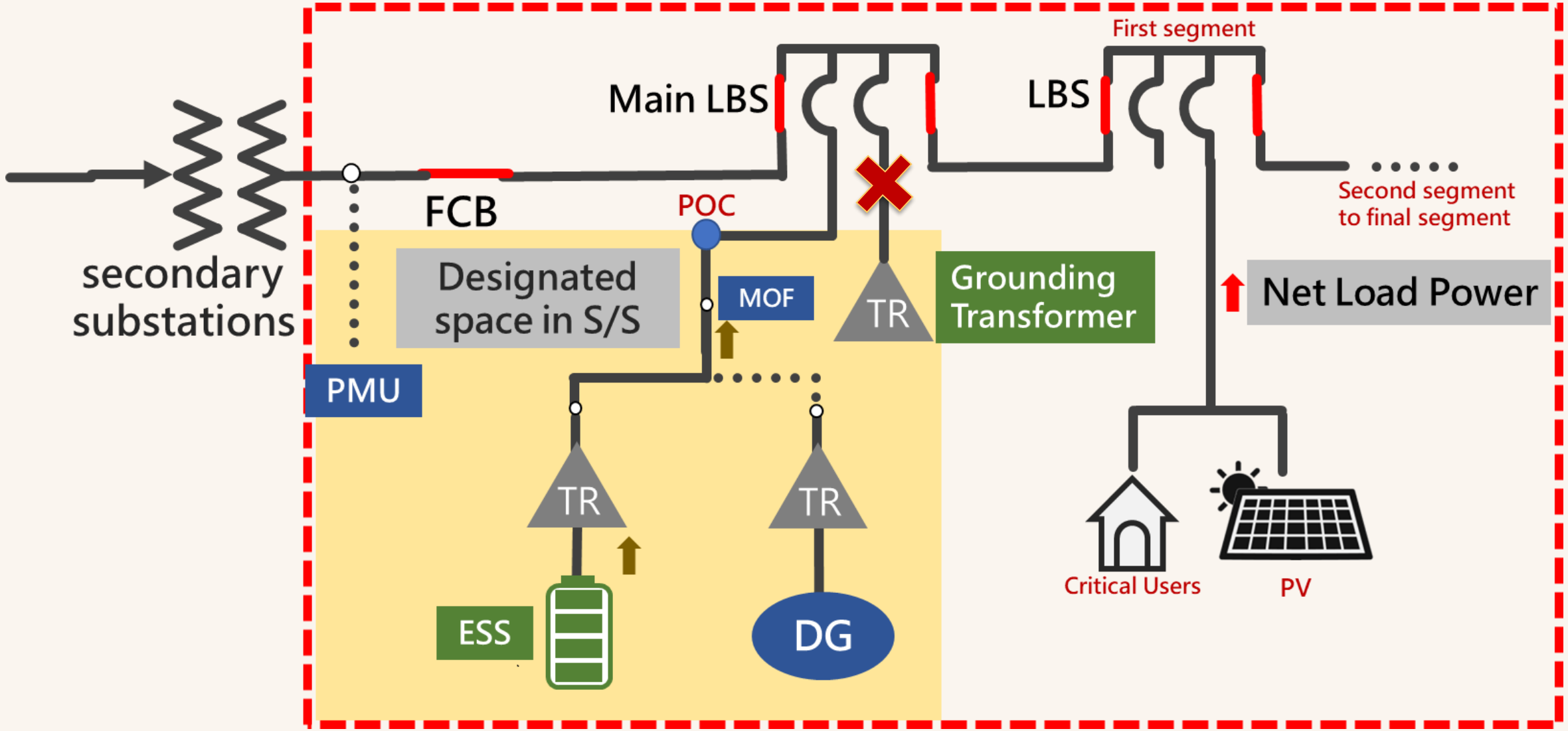
0.6 billion USD in 3 years to complete installation and system test (2023-2025)



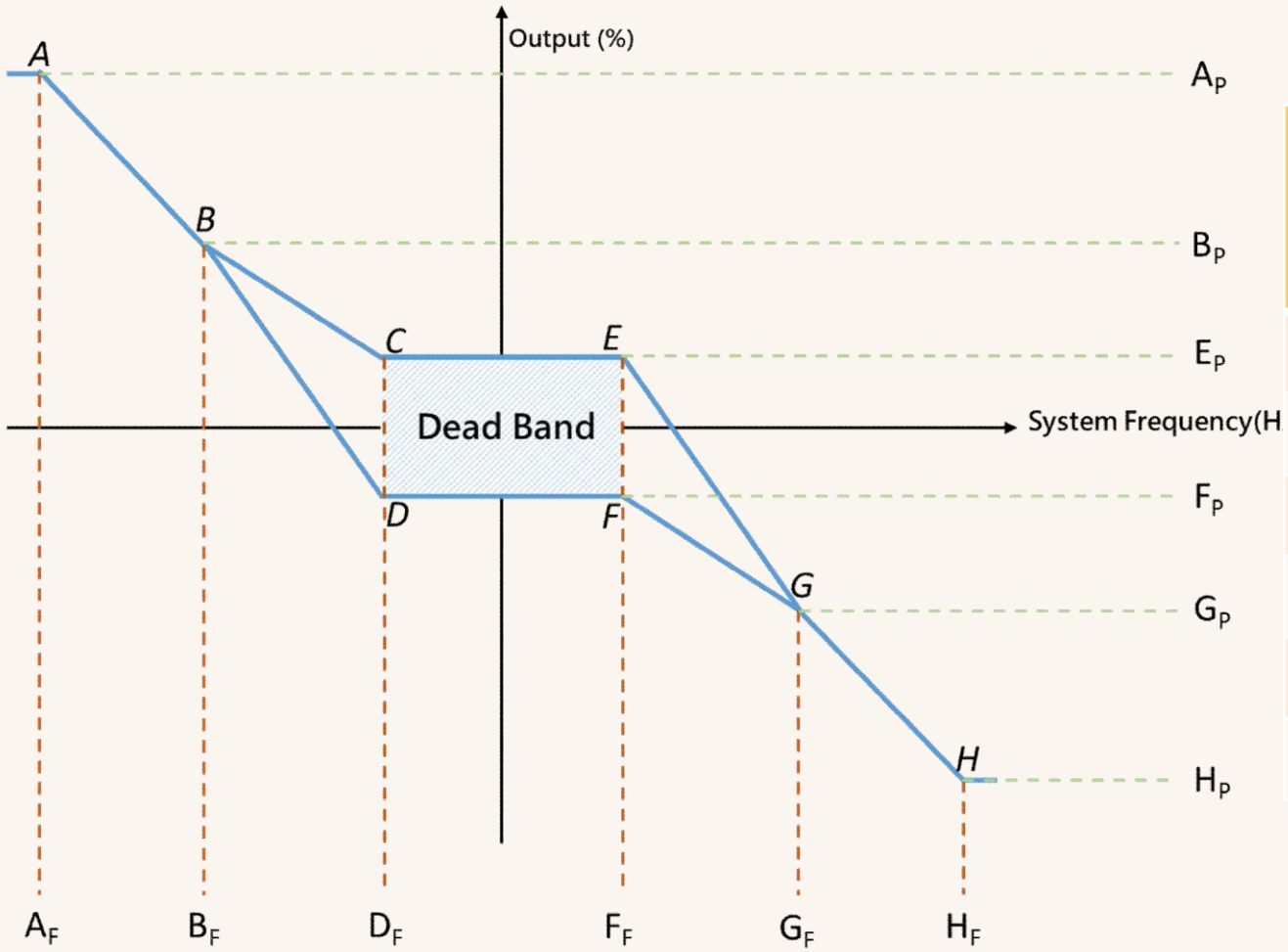
Chiayi County

5MW/6.28MWh

Grid-Connected Mode



Automatic Frequency Control



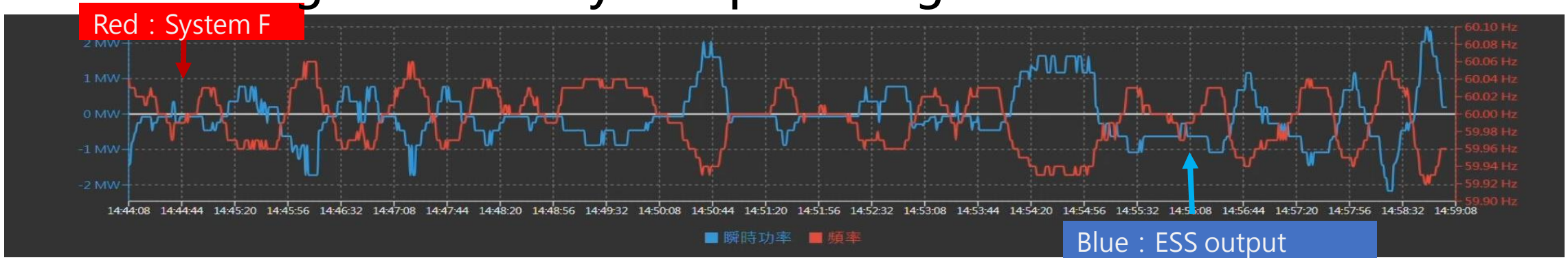
System Frequency (dReg0.25)	System Frequency (dReg0.5)	Correspo-nding Index	Correspo-nding Index
59.75Hz	59.50Hz	AF	AP
59.86Hz	59.75Hz	BF	BP
59.98Hz	59.98Hz	DF	EP/FP
60.02Hz	60.02Hz	FF	FP/EP
60.14Hz	60.25Hz	GF	GP
60.25Hz	60.50Hz	HF	HP

Automatic Frequency Control (by EMS)

Chiayi Site
AFC Mode
At TPC FDCC

AFC & PV Smoothing

1. perform instantaneous charging and discharging according to the AFC curve setting to assist in system power regulation.



2. smooth the intermittent impact of PV power and help feeders increase the capacity.

ESS and Diesel Generator Information

Chiayi Site
EMS
from TPC FDCC

Inverter_ Inverter 控制	停止
PCS自動模式	停止
PCS併網運轉	停止
柴油發電機控制	停止

綜合資訊	狀態
Communication with EMS Stat	正常
EMS Enable/Disable	Enable
EMS-Power Up	正常
通訊狀態	正常
案場用電狀態	市網供電
市電併聯控制_執行狀態	執行
孤島供電控制_執行狀態	A 停止
儲能電池組_電池電壓過高	正常
儲能電池組_電池電壓過低	正常
儲能電池組_平衡電路異常	正常
PCS_運轉狀態	A 停止
柴油發電機_ 運轉狀態	停止
Main CB狀態	投入

PCS系統	讀值
總負載用電功率	0.00 KW
太陽能日照量(目前日照量)	0.00 MJ/m2
總PV 發電電功率(總實際發電量)	0.00 KW
儲能系統容量	5895.00 KWH
儲能系統運轉功率	-38.60 KW
儲能系統容量百分比	92.40 %
自動卸載電流	0.00 A
自動復歸電流	0.00 A
充電機_目前輸出功率	0.00 KW
需量控制_設定容量	0.00 KW
需量控制_目前需量	0.00 KW
需量控制_預測需量	0.00 KW
需量控制_最大需量	0.00 KW
PCS AC電壓	11.81 KV
PCS 頻率	59.96 HZ

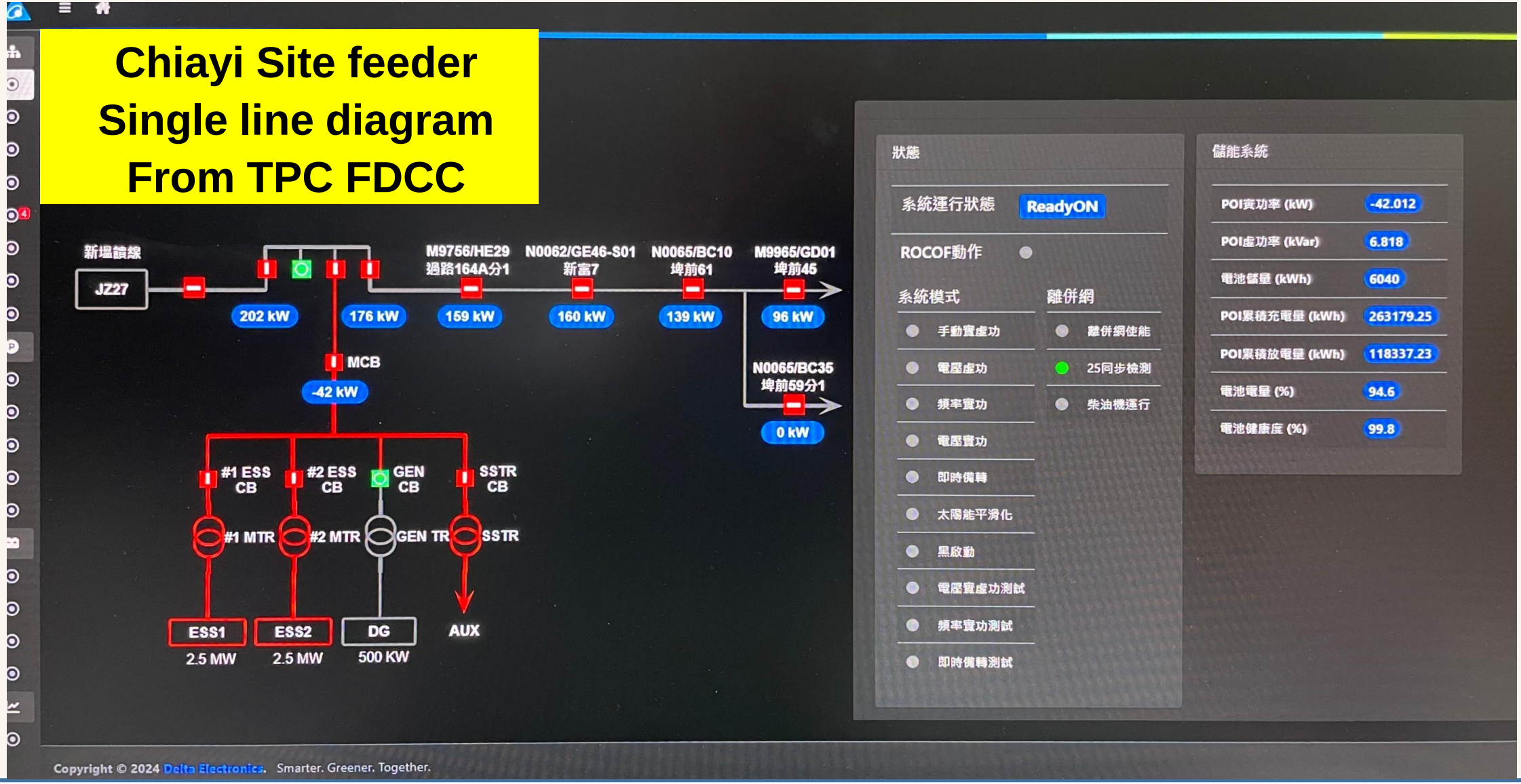
PCS系統	狀態
市電併聯控制_執行狀態	執行
孤島供電控制_執行狀態	A 停止
儲能電池組_電池電壓過高	正常
儲能電池組_電池電壓過低	正常
儲能電池組_平衡電路異常	正常
PCS_運轉狀態	A 停止
PCS_P	-38.00 KW
PCS_Q	8.00 KW
PCS_P	-38.0 KW
PCS_Q	8.0 KW

發電機資訊	狀態
柴油發電機_ 運轉狀態	停止
柴油發電機_發電機功率(輸出功率	0.00 KW
柴油發電機AC電壓	11.81 KV
柴油發電機頻率	59.96 HZ
柴油發電機 P	0.00 KW
柴油發電機 Q	0.00 KW
柴油發電機 P	0.0 KW
柴油發電機 Q	0.0 KW

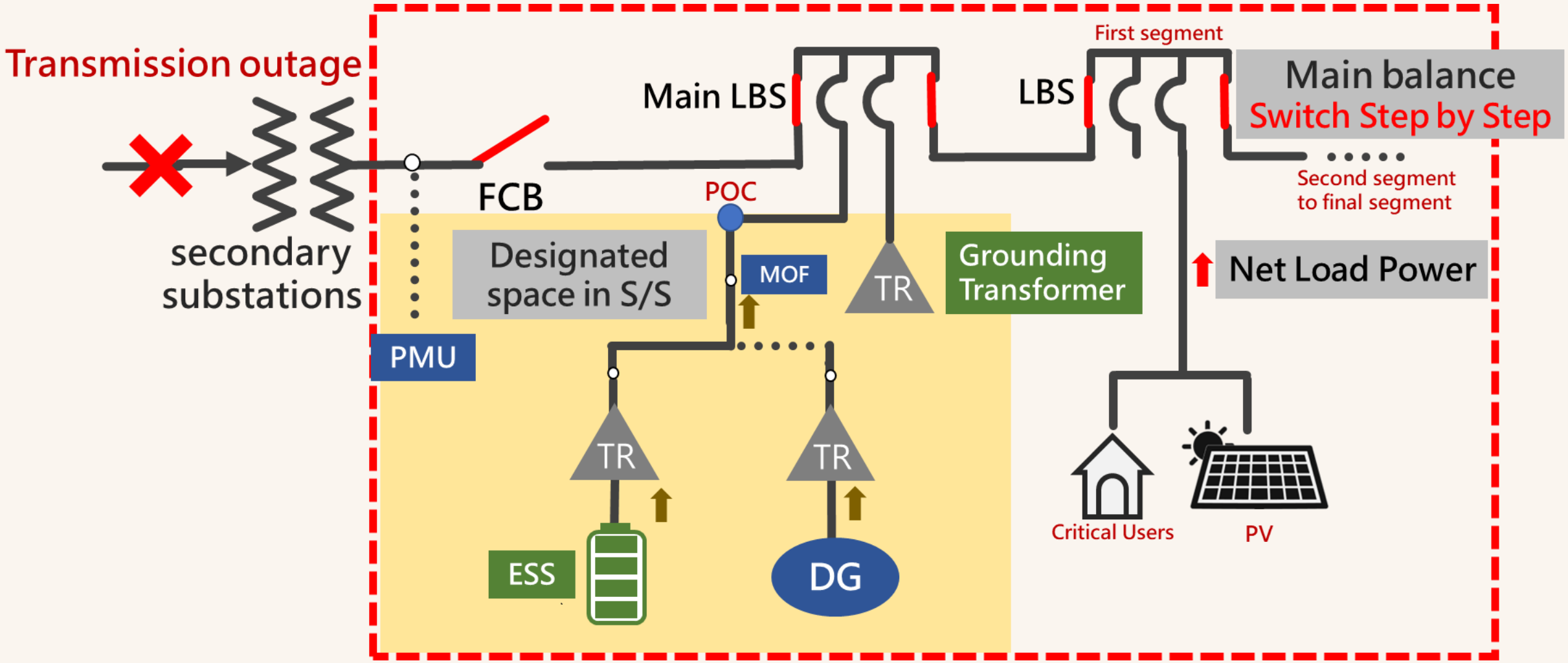
ACC資訊	讀值
台電側	118680.1 KWH+
台電側	270618.9 KWH-
台電側	42458.3 KVarH+
台電側	10415.9 KVarH-
負載側	0.0 KWH+
負載側	0.0 KWH-
負載側	0.0 KVarH+
負載側	0.0 KVarH-
PV	0.0 KWH+
PV	0.0 KWH-

Feeder Power Information

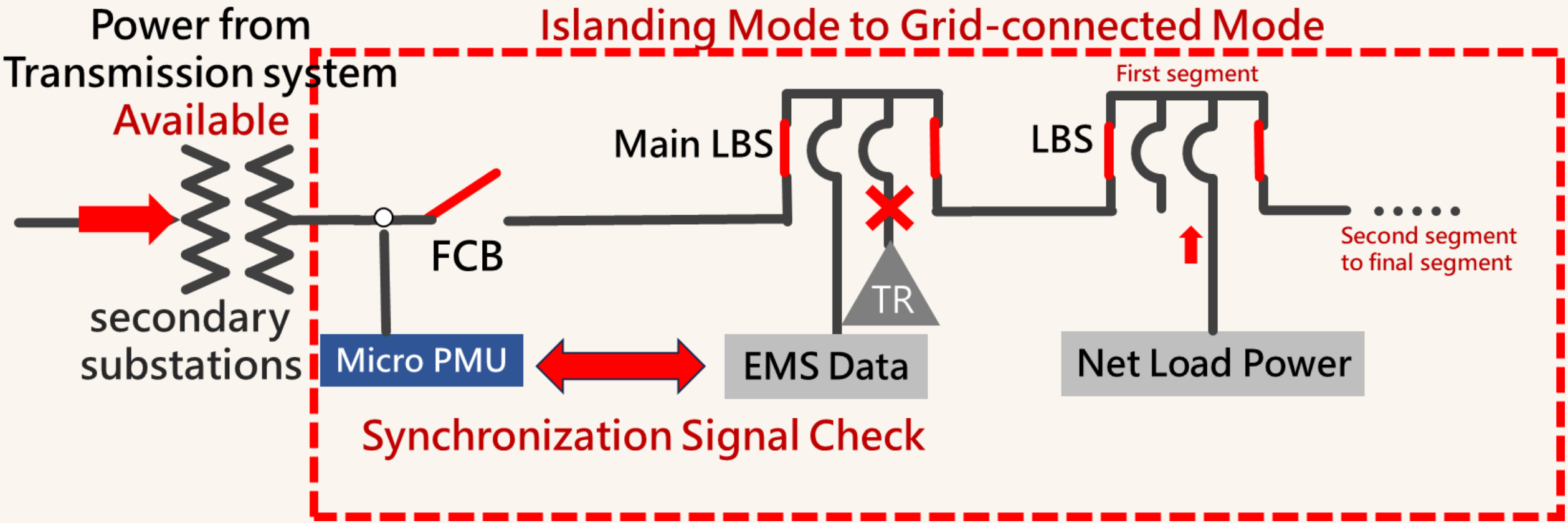
Chiayi Site feeder
Single line diagram
From TPC FDCC



Black Start and Islanding Mode

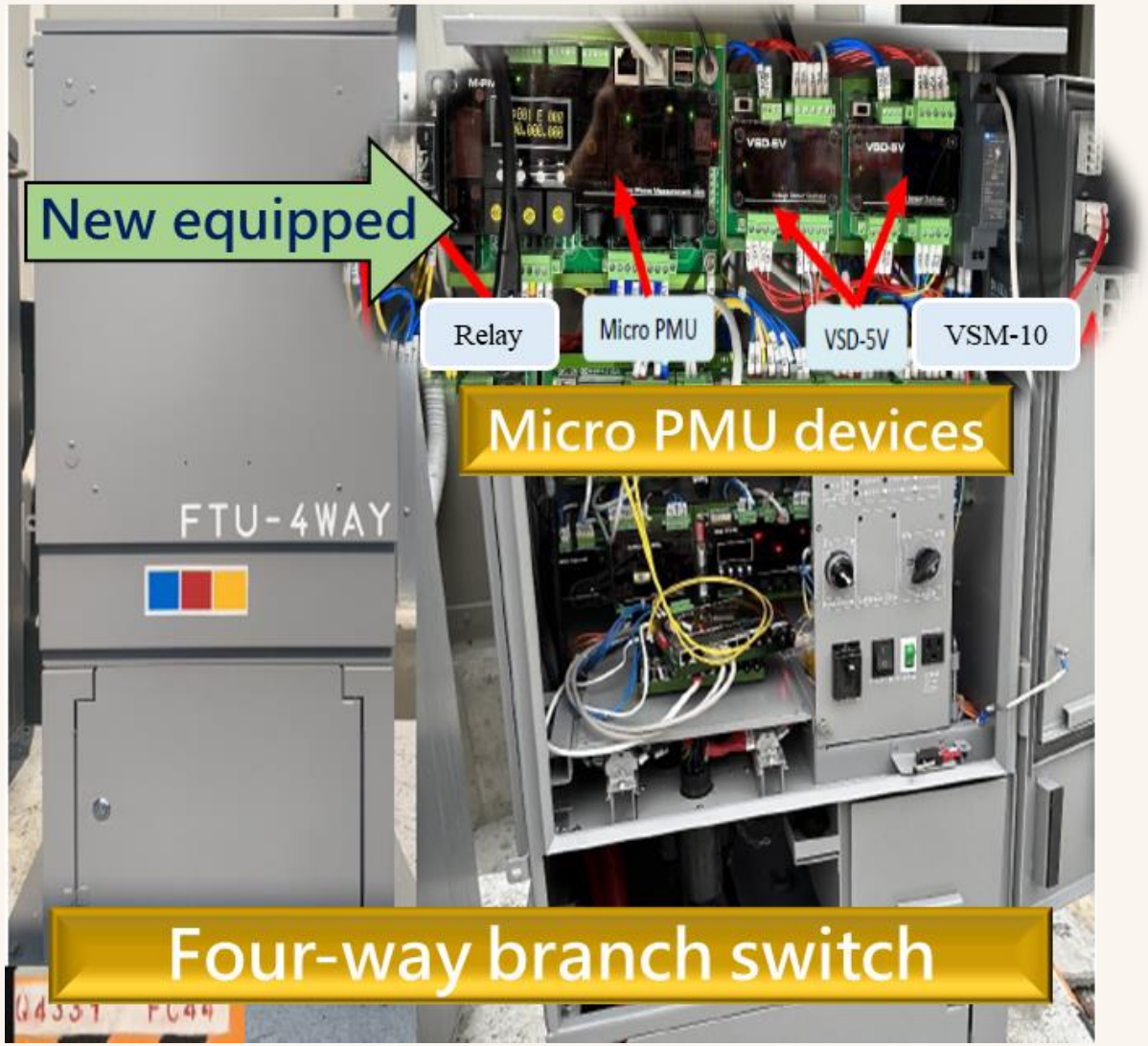


Restoration Procedure



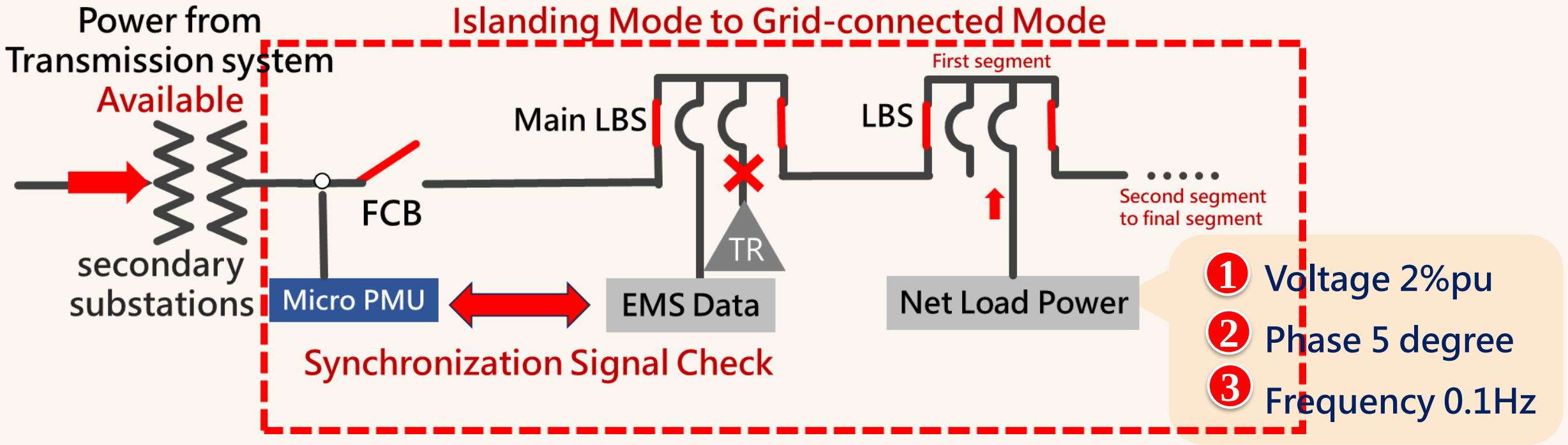
PMU captures power information

- To dynamically collect the real-time net load information of each segment of the feeder, we install the Micro PMU measurement module in the FTU-4WAY.
- Then, transmit data back to the EMS, and record the historical information to establish the background value as a reference for emergency scheduling and islanding mode load forecast.



Back To Grid-Connected Mode

- To Switch from an islanding mode to grid connected mode, the power synchronization condition requires that the "voltage, phase angle and frequency" on the grid side (A) and the power side (B) be consistent.
- To confirm the synchronization signal, the FCB then closes.

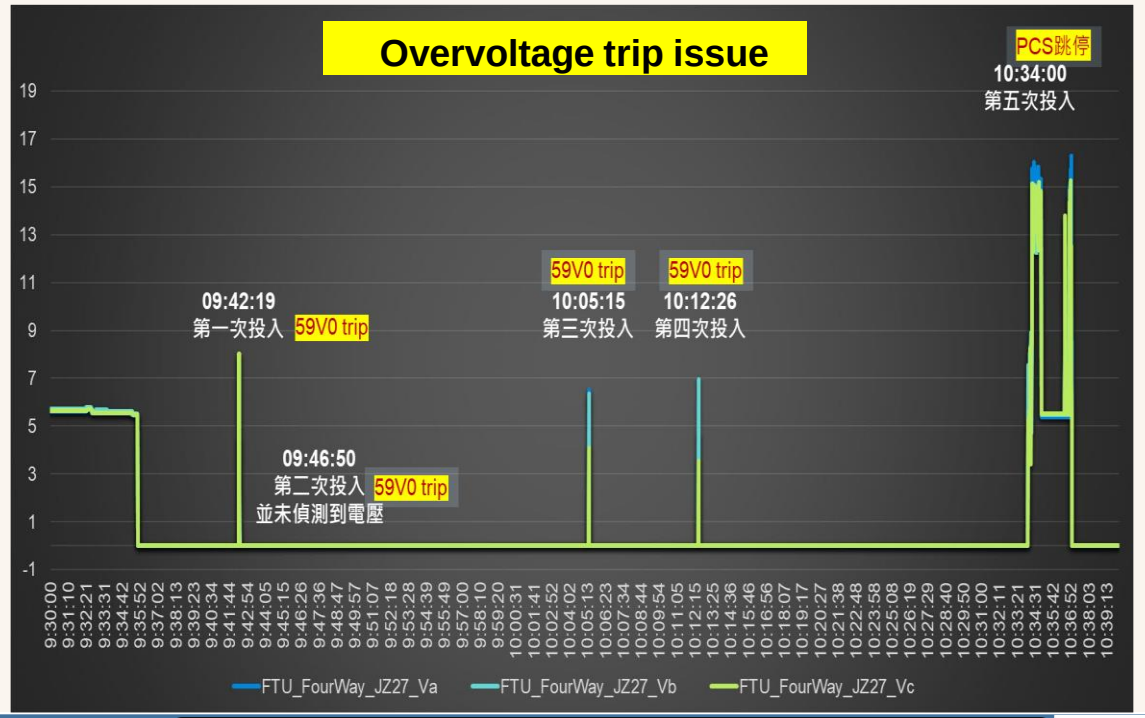


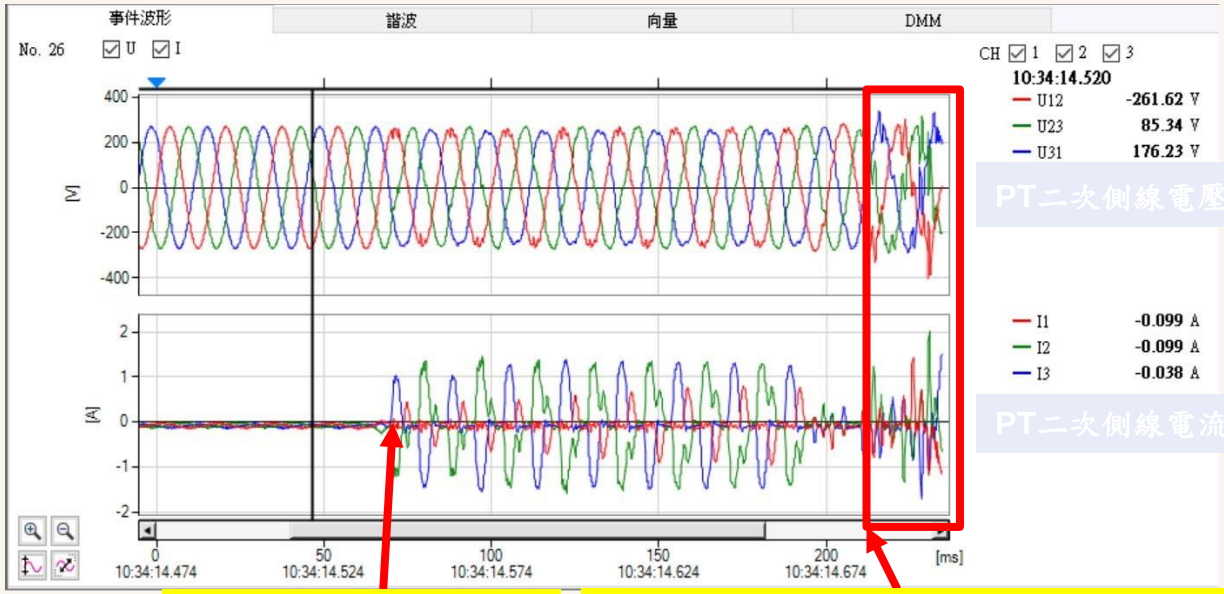
PART 3

Technical Challenges

Islanding test – Ungrounding issue

- In Islanding mode, if lacks dedicated grounding reference, it could practically lead to voltage imbalance when single-phase loads are connected, causing neutral point voltage drift, harmonic current.





10:34:14.54 Islanding starts

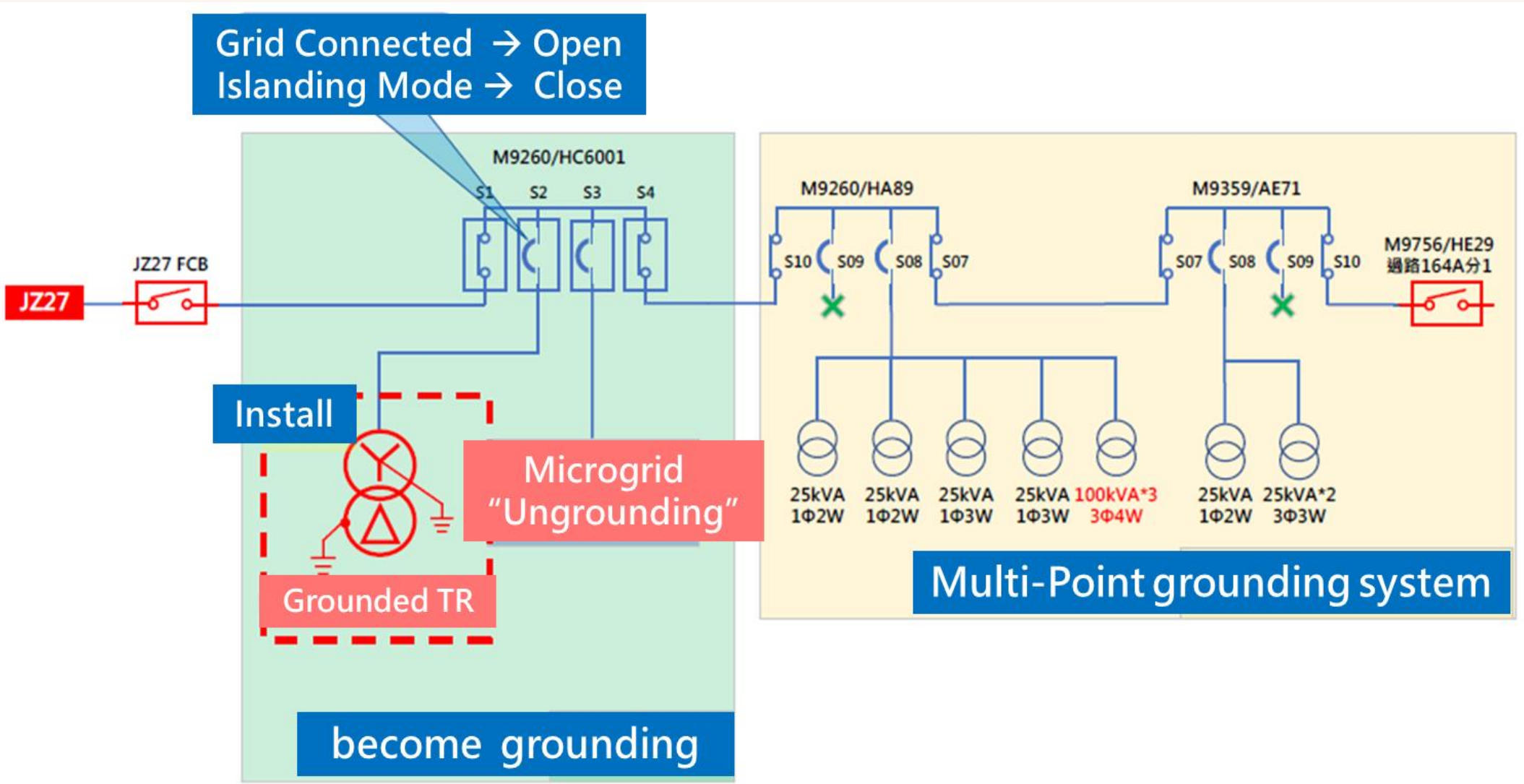
10:34:14.68 Current oscillation affects voltage. Abnormal current/voltage waveform

Three-phase voltage unbalance

3rd and 5th Harmonic Current occur within 50ms after islanding starts

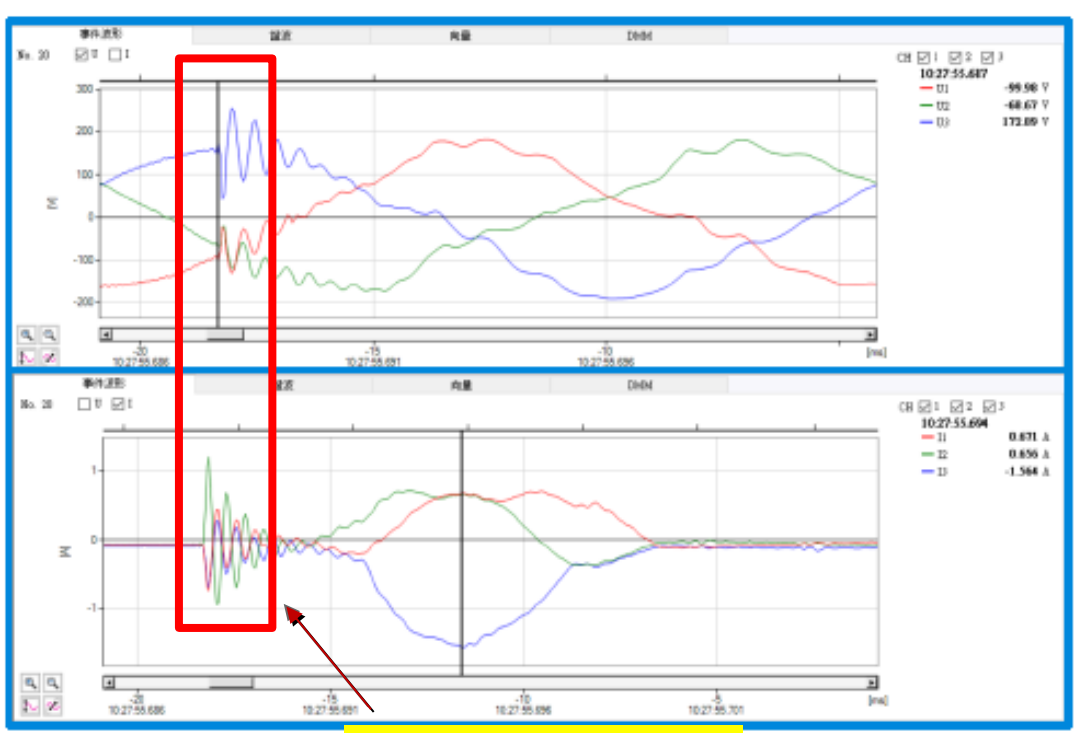
Grounding effective

- Equipped with supplemental grounding mechanisms by installing grounding transformers.
- Reconfigured to a Yg-Δ wiring scheme to ensure having a stable reference ground.



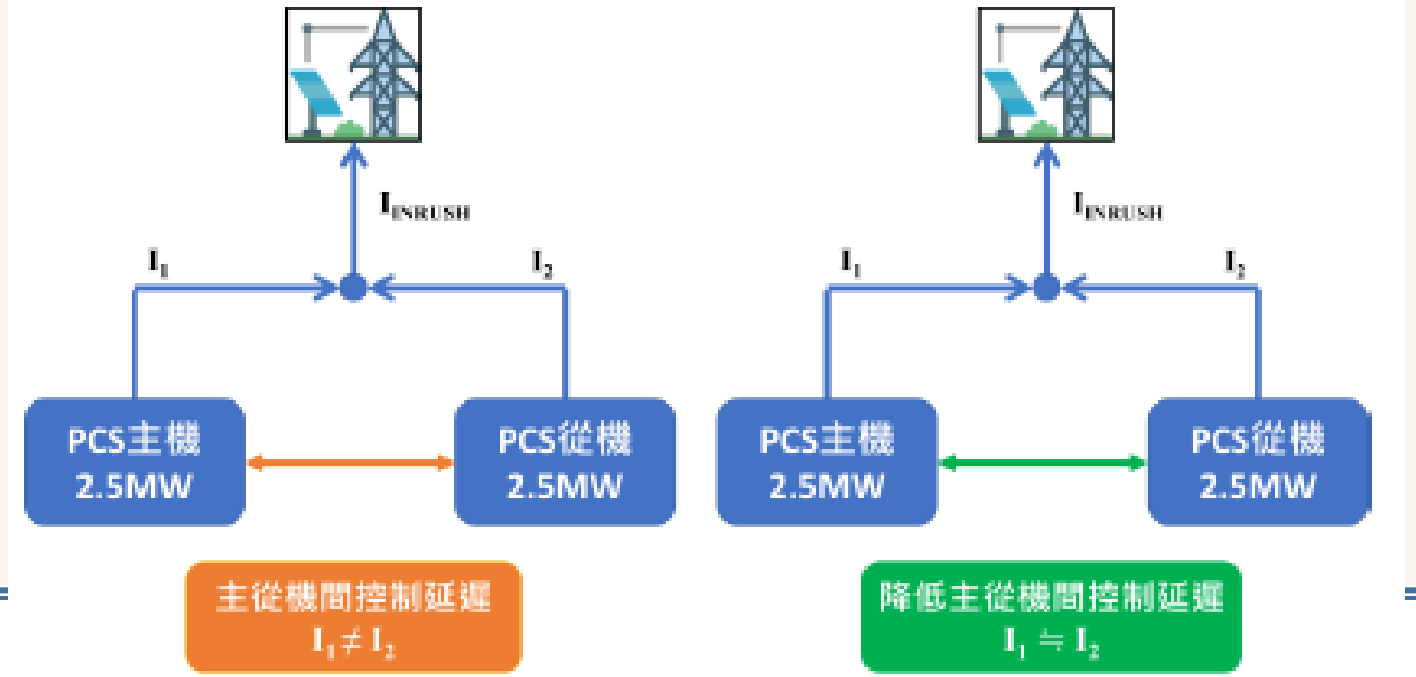
Islanding test – Inrush Current issue

- After islanding begins, it showed unpredictable spikes immediately, needed demanding robust control strategies.
- Field tests showed that these currents could reach up to 8 times the rated steady-state current randomly, pose a risk to the PCS, cause shutdown due to protection relay mechanism.



To shave the impact of Inrush Current

- **Segmented reconnection strategy** : The total transformer capacity for each feeder segment was reviewed to ensure that PCS could handle inrush current surges within safe limits magnitude.
- **Enhanced PCS response speed** : Improved through technology development by manufactures, the PCS control loop was optimized to react quickly to sudden current changes, reducing the risk of overcurrent protection being triggered.
- **Distributed control strategy** : Instead of relying on a single PCS unit, multiple PCS units were programmed to operate in a master-slave configuration, dynamically distributing inrush current among all available units.



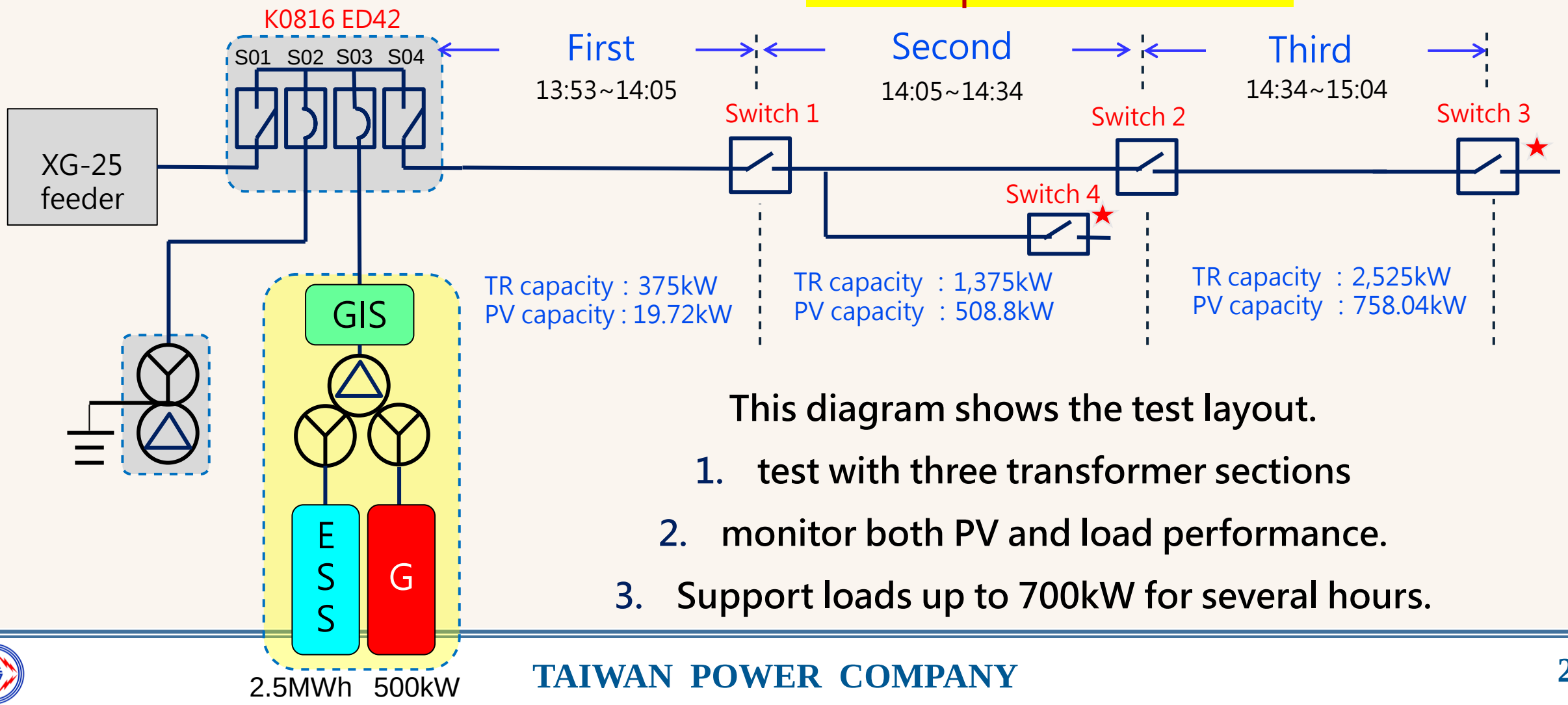
PART 4

Islanding Mode Test Results

Black Start - Islanding test

Yunlin Site islanding

Total load：669.5 kW
PV output ：700.5 kW

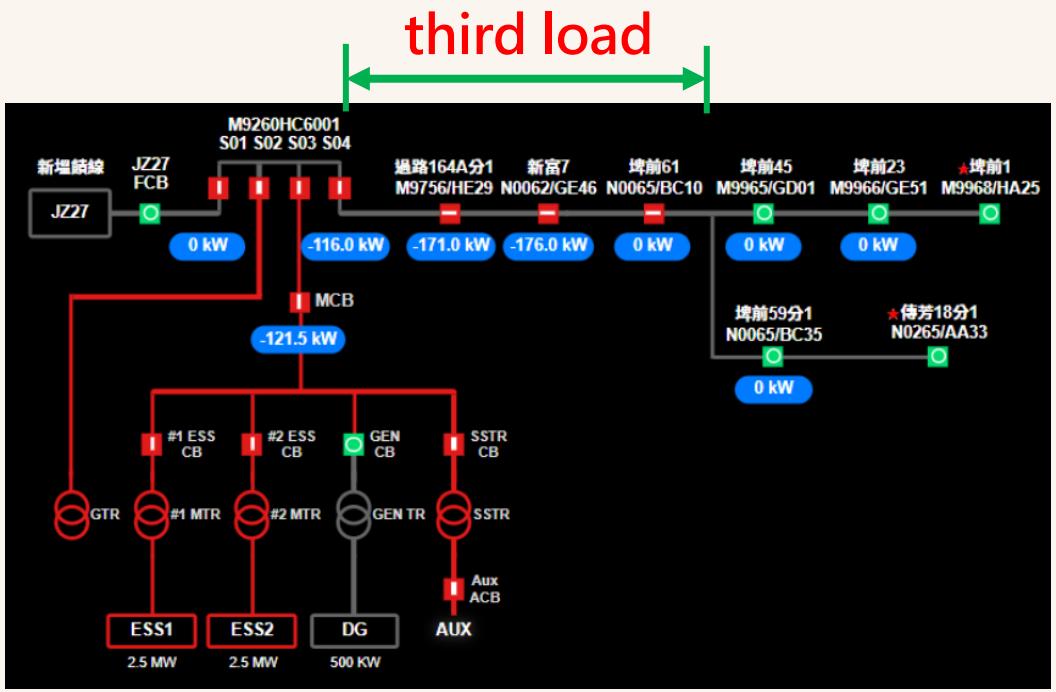


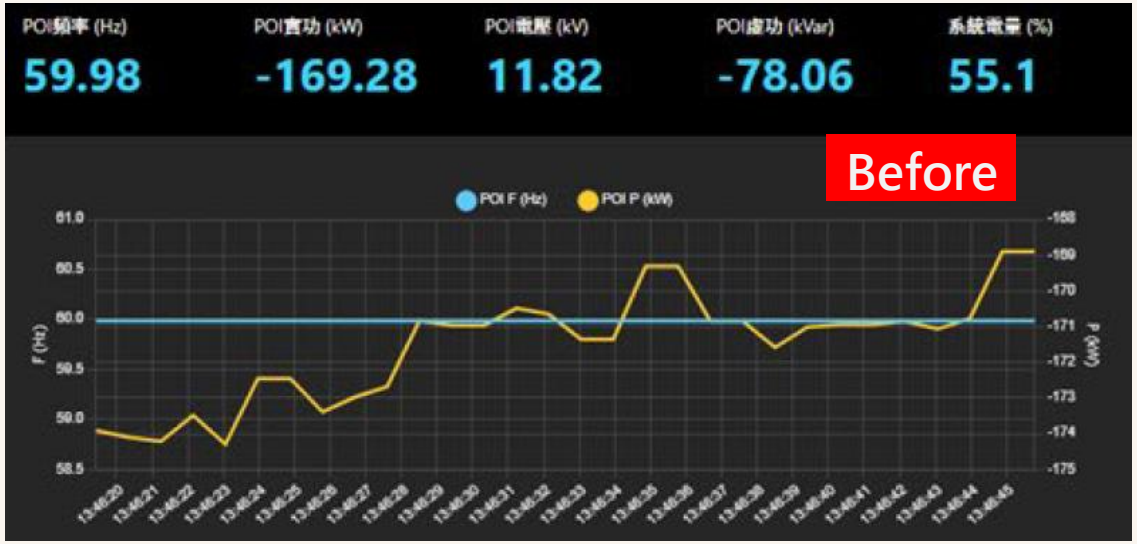
This diagram shows the test layout.

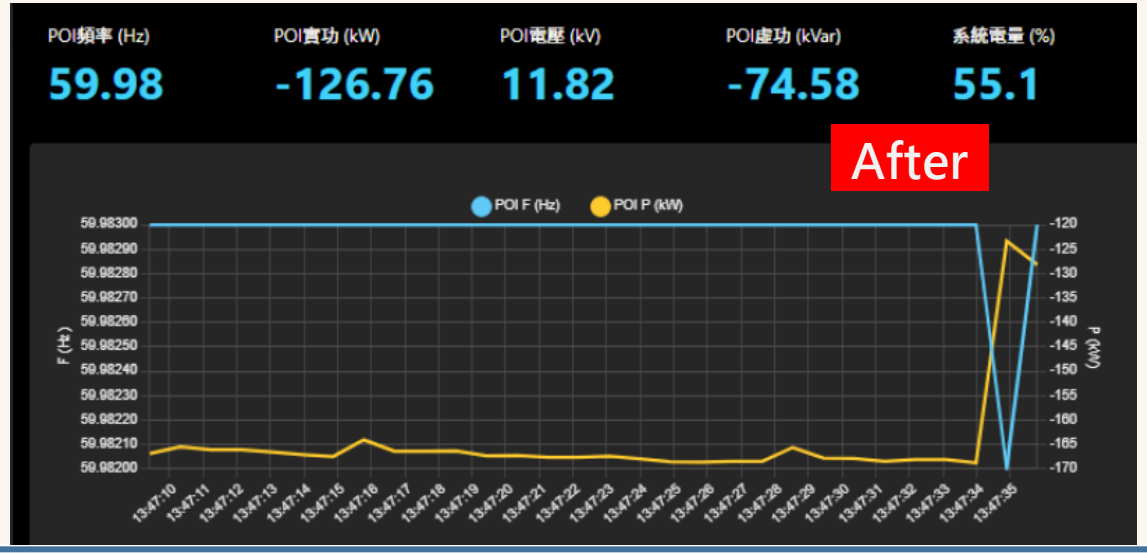
1. test with three transformer sections
2. monitor both PV and load performance.
3. Support loads up to 700kW for several hours.

Black Start - Islanding test

Verify the third load input when islanding





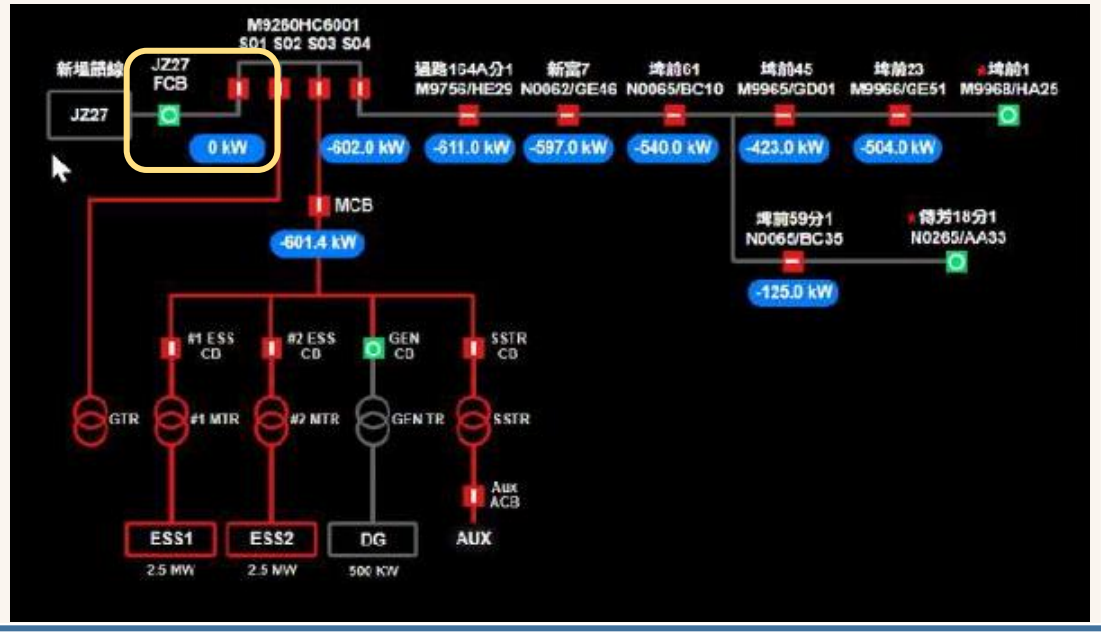


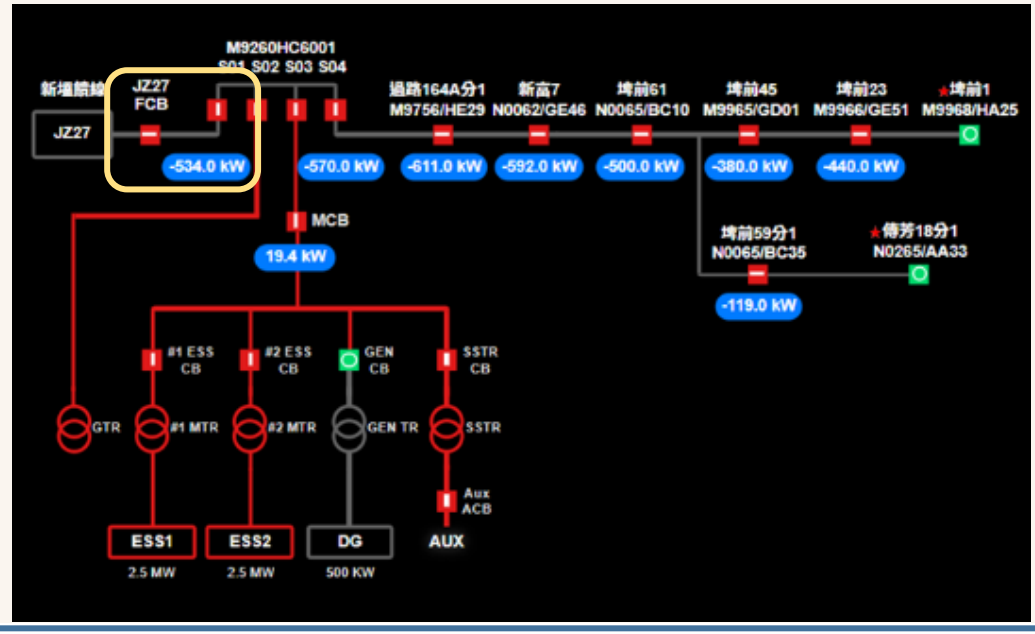
Restoration Procedure Seamless test

Back to grid-connected mode

synchronization signal check

FCB close





Multiple Test Results

- Yunlin Yun-Kang Site : Islanding operation sustained for 90 minutes, supplying 725 kW from storage, 340 kWp from PV, and a total load of 1,065 kW.
- Chiayi Xin-Wen Site : Islanding operation lasted 120 minutes, with 1,400 kW charging from storage, 2,000 kWp from PV, and a total load of 600 kW.
- Tainan Nan-Hua Site : Islanding operation lasted 90 minutes, supplying 19 kW from storage, 520 kWp from PV, and a total load of 539 kW.
- Pingtung Xin-Wei Site : Islanding operation continued for 30 minutes, delivering 1,172 kW from storage, 2,492 kWp from PV, and a total load of 1,320 kW.

Conclusion

- Battery storage + solar successfully supported local loads — proving the viability of islanded microgrids, show the technical for Black Starts and Seamless integration.
- Energy storage playing a crucial role during the microgrid transformation, not only a technical milestone, but a strategic blueprint. It leads distribution system into a more resilient and sustainable. When the emergency occurs, the power is ready to provide.
- More than hardware and megawatts, also about building Public Trust.

  Trust that —when the lights go out, the system will recover;
  when the demand spikes, the system will respond;
  when the future arrives, the system will be ready.