AVEVA PI WORLD

Operating and Optimizing Renewable Power and Distributed Energy Resources

Taiwan Power Company

Taiwan Power Research Institute

LI-FEN CHOU

Agenda

- Taiwan Power Company Overview
- Increasing Challenge of Renewables
- PI System in Taiwan Power Company
- Forecasting Renewables, Methods and Results
- Distributed Energy Resources
- Summary

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Taiwan Power Company (TPC)

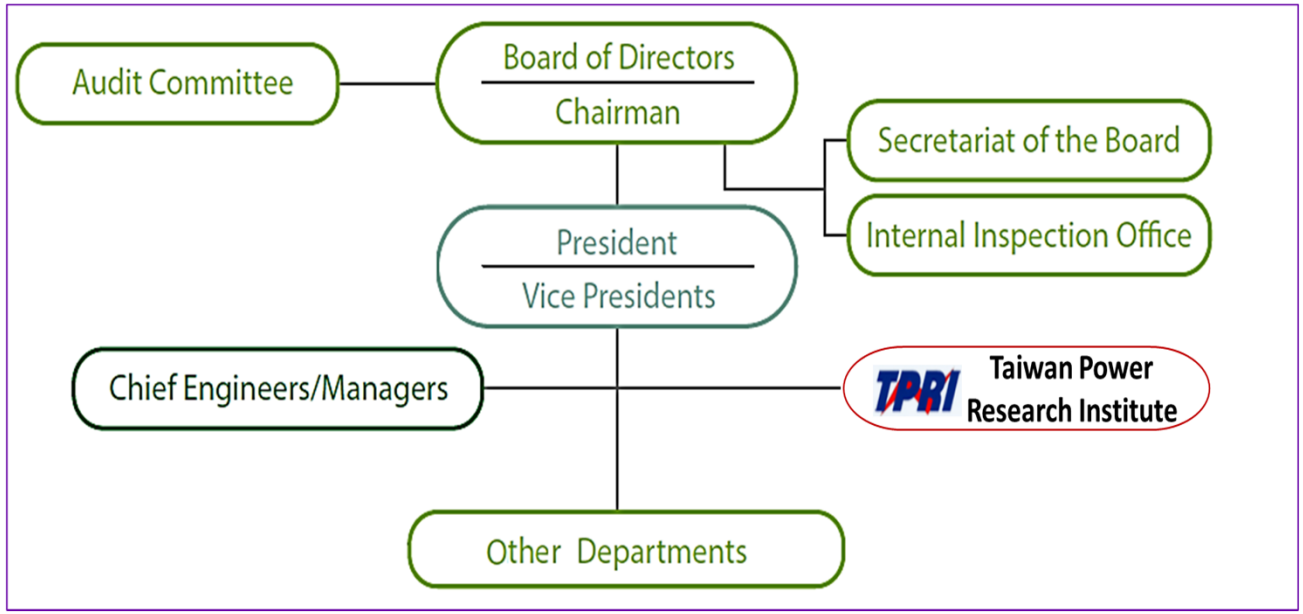
- **Founded**: May 1, 1946
- **Headquarter**: Taipei, Taiwan
- **Capital**: NT$330B/US$12B
- **Stock**: Government-Owned 96.92%
  Private-Owned 3.08%

- **Employees**: ~28,000
- **Service**: ~24 million population
  ~15 million customers
- **Installed capacity**: ~45 GW
  (TPC-owned 35 GW, 70+%)

Taiwan Power Research Institute (TPRI)

台灣電力公司綜合研究所
Taiwan Power Research Institute Taiwan Power Company

Organizational Structure of TPC



※Taiwan Power Research Institute reports to the President directly

- TPRI is one of the departments that possess core technologies and professional skills in TPC.
- Under TPC's integrated developing objectives and strategies, TPRI is responsible for short-mid-long term R&D planning, technical research and innovation testing, etc.

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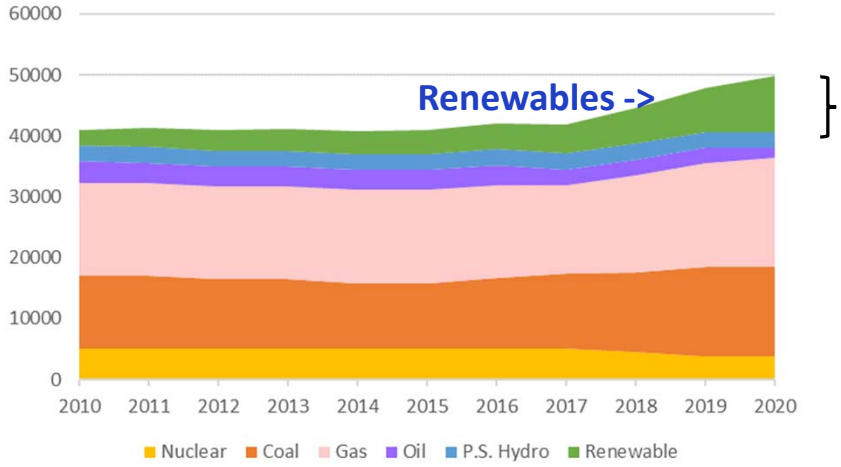
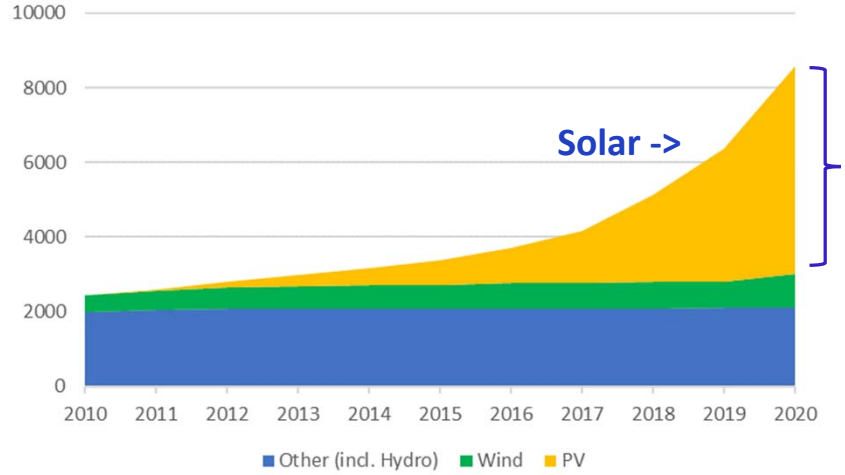
TPC Installed Capacity by Energy Type

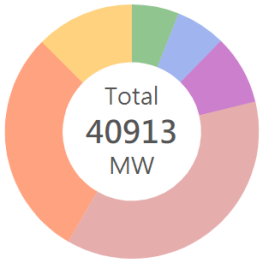


Renewable & Intermittency

Increasing

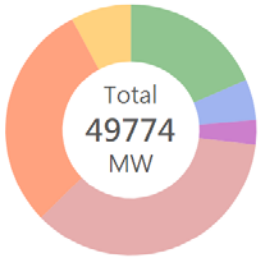


Installed Capacity in 2010



Renewable	6.0 %
P.S. Hydro	6.4 %
Oil	8.9 %
Gas	37.1 %
Coal	29.1 %
Nuclear	12.6 %

Installed Capacity in 2020



Renewable	18.5 %
P.S. Hydro	5.2 %
Oil	3.2 %
Gas	35.8 %
Coal	29.5 %
Nuclear	7.8 %

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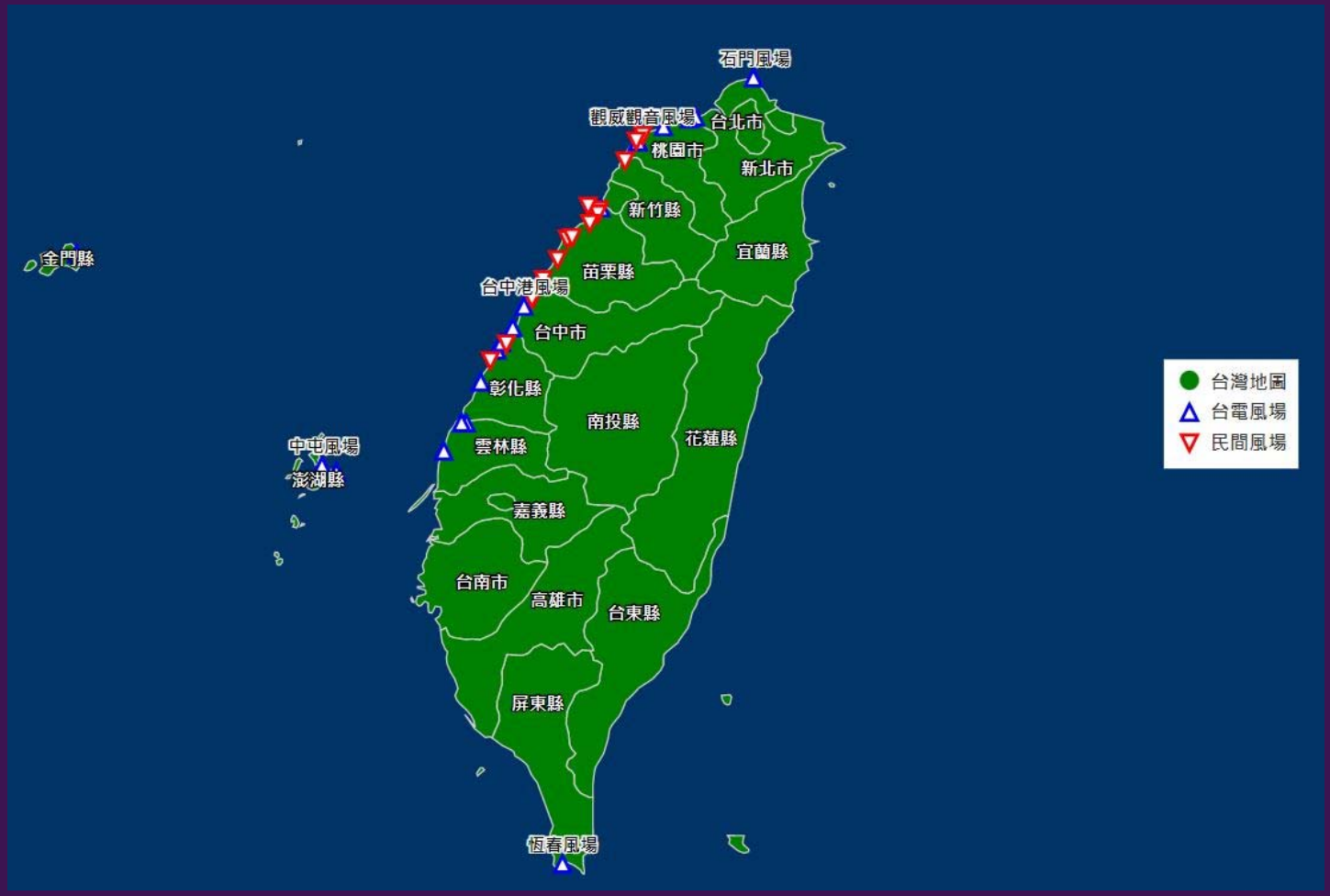
Wind Farms in Taiwan



TPC-owned

onshore: 312 MW
offshore: 109.2 MW

Non-TPC

onshore: 526 MW
offshore: 128 MW

2025 (projected)

onshore: 1.2 GW (+43%)
offshore: 5.5 GW (+2200%)

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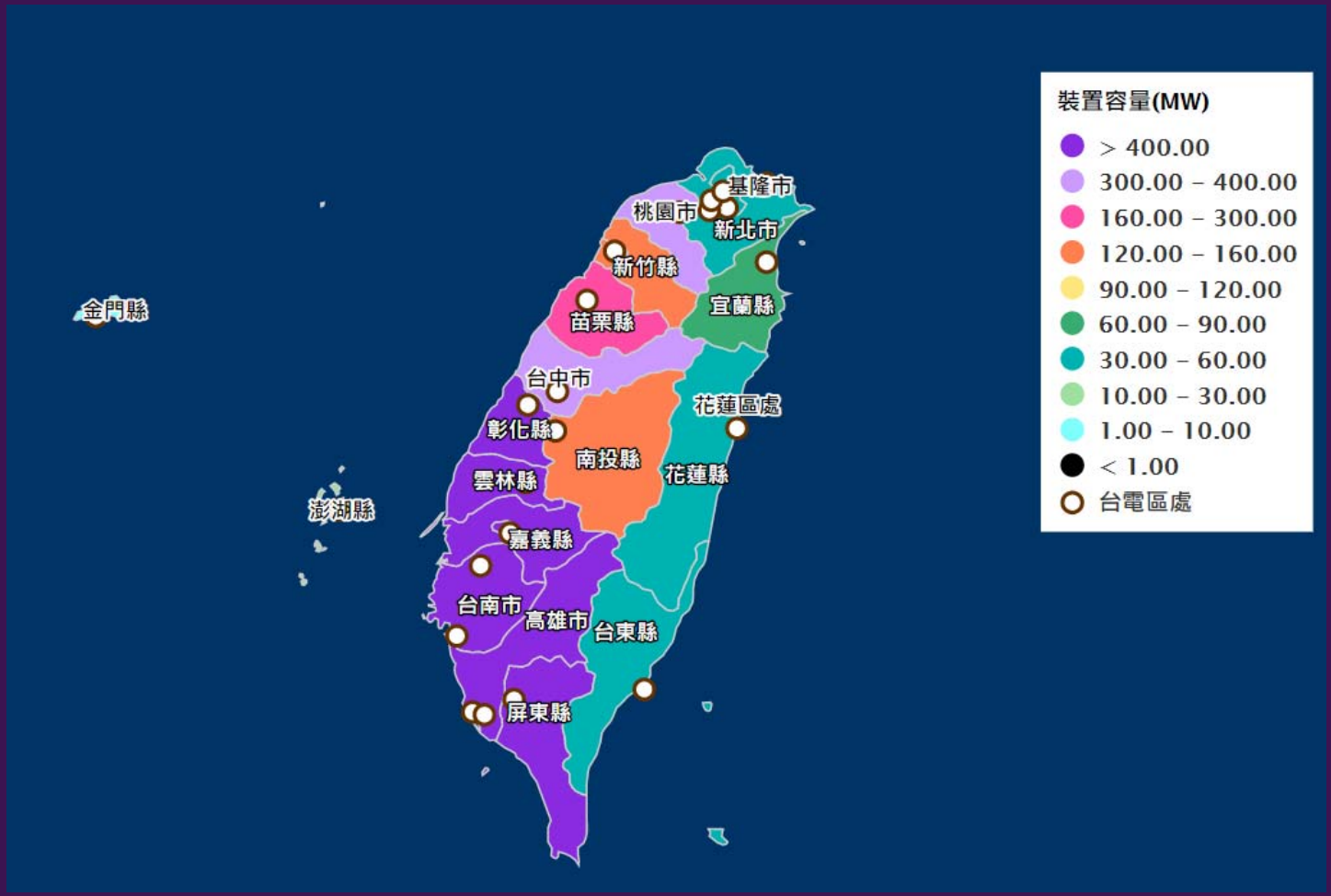
Solar (PV) in Taiwan



TPC-owned

283 MW

Non-TPC

6.3 GW

2025 (projected)

20 GW (+200%)

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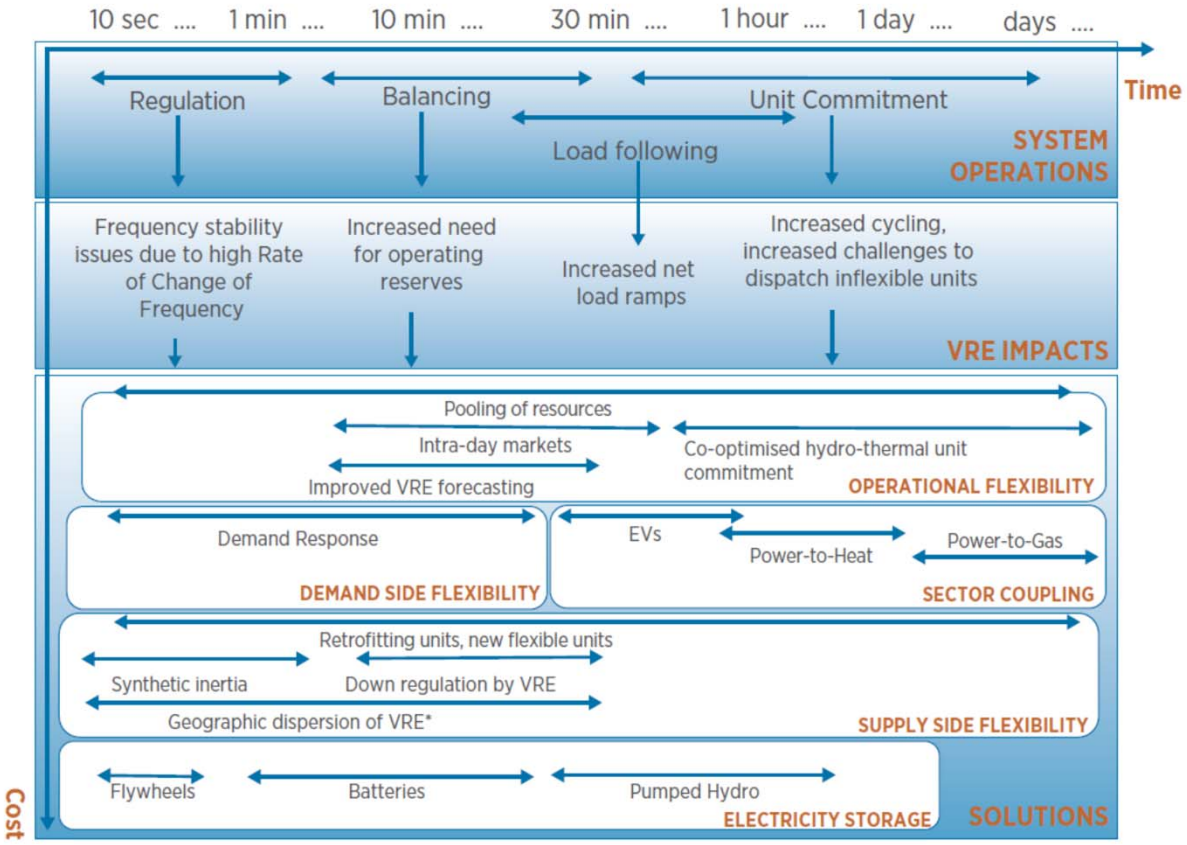
Impacts of Variable Renewable Energy (VRE)



Challenge

In last decade, the growing penetration and aggressive goal of wind and solar power have posed challenges to TPC, the only power system operator in Taiwan, in grid management and generation scheduling due to the inherent intermittency and variability of renewable energy.

Solution

To cope with the challenges, real-time monitoring and forecasting systems based on machine learning have been developed by leveraging PI System large volume of operations data and PI System tools for system and data integration foundation

Benefits

Better use of real-time and historical data, developing renewable power forecasting methods to assist system operations, optimize and maximize large-scale renewable integration

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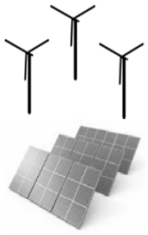
TPRI PI System



PI Interfaces

RE. PI Server

PI to PI Interface

TPRI PI Web Server

TPRI PI Server

TPRI PI AF Server

PI Web API

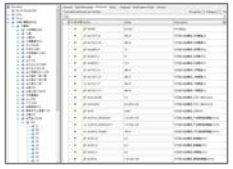
Historical Data Retrieval User Interfaces

PI Client Tools

PI Vision:
Access PI System data from any user, any device and anywhere

AF SDK to Json

Real-Time Solar Generation Forecasting System



OPC DA Server

ARIMA Wind Generation Forecasting System

RDBMS Interface

Solar Energy Reference Base Systems
MS SQL

Direct Access™

Renewable Generation Forecasting System
Matlab

PI BA Integrator

Renewable Generation Analysis System

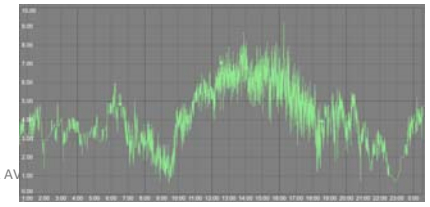
PI Client Tools

Reference Base Station Solar Real-Time Operations Information

Wind Turbine Real-Time Operations Information

Solar Station Real-Time Operations Information

PI Visualization:
Real-time monitoring
Performance Analysis and Fault Diagnostic



PI DataLink:
Reporting

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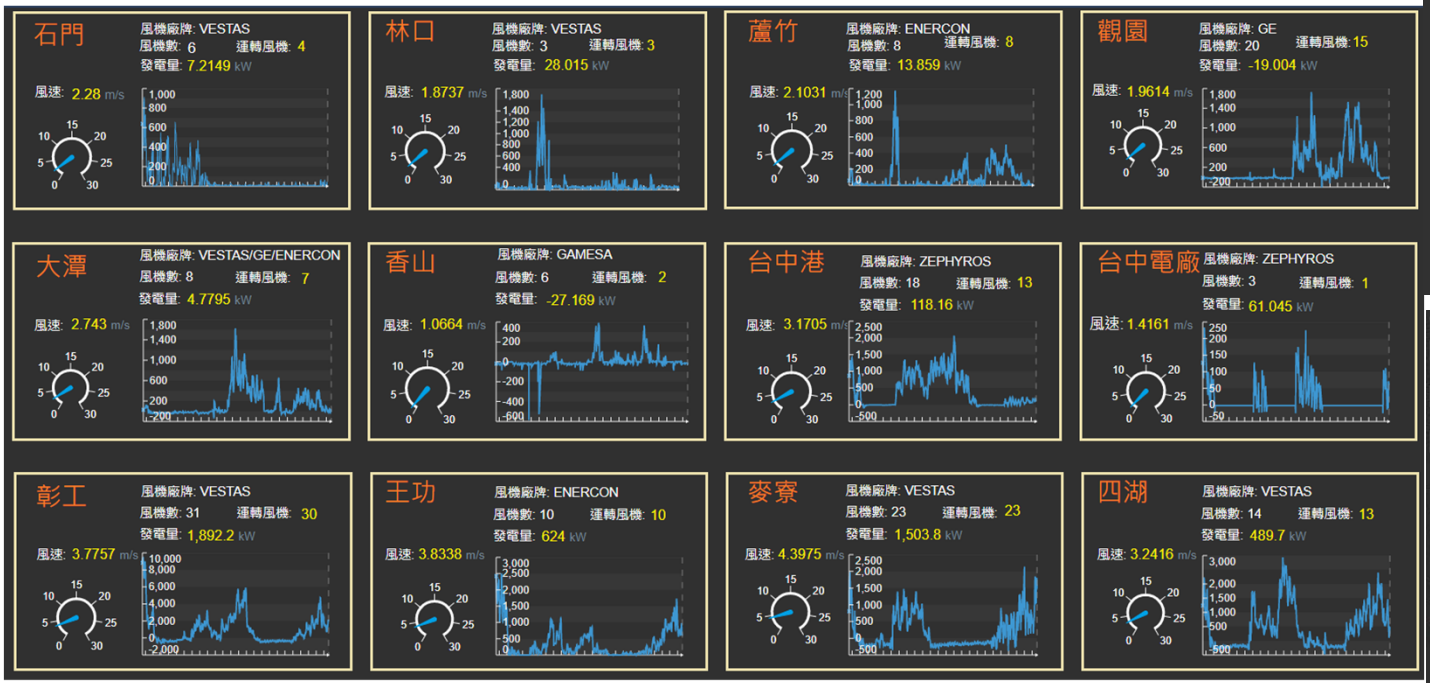
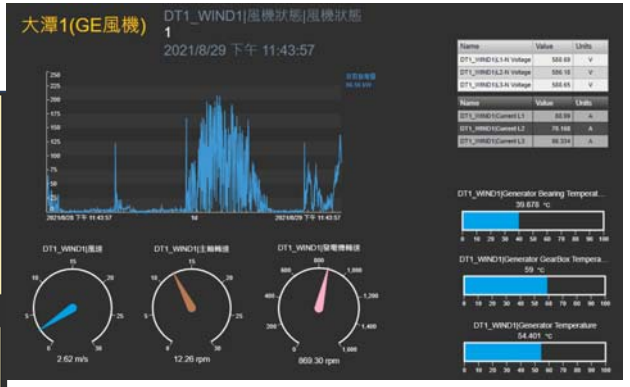
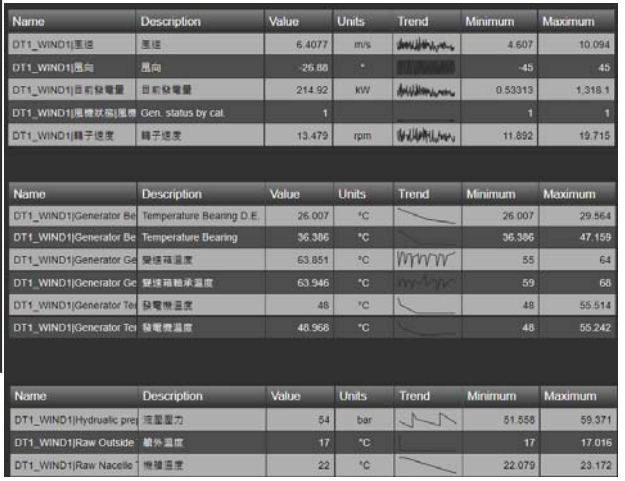
Dep. of Renewable PI System for Wind Generation

Wind Farm Real-Time Monitoring and Operations







Name	Description	Value	Units	Trend	Minimum	Maximum
DT1_WIND1|風速	風速	6.4077	m/s		4.607	10.094
DT1_WIND1|風向	風向	-26.88	°		-45	45
DT1_WIND1|目前發電量	目前發電量	214.92	kW		0.53313	1,318.1
DT1_WIND1|風機狀態|風機	Gen. status by cal.	1			1	1
DT1_WIND1|轉子速度	轉子速度	13.479	rpm		11.892	19.715

Name	Description	Value	Units	Trend	Minimum	Maximum
DT1_WIND1|Generator Be	Temperature Bearing D.E.	26.007	°C		26.007	29.564
DT1_WIND1|Generator Be	Temperature Bearing	36.386	°C		36.386	47.159
DT1_WIND1|Generator Ge	變速箱溫度	63.851	°C		55	64
DT1_WIND1|Generator Ge	變速箱軸承溫度	63.946	°C		59	68
DT1_WIND1|Generator Te	發電機溫度	48	°C		48	55.514
DT1_WIND1|Generator Te	發電機溫度	48.968	°C		48	55.242

Name	Description	Value	Units	Trend	Minimum	Maximum
DT1_WIND1|Hydrualic pre	液壓壓力	54	bar		51.556	59.371
DT1_WIND1|Raw Outside	艙外溫度	17	°C		17	17.016
DT1_WIND1|Raw Nacelle	機艙溫度	22	°C		22.079	23.172

- Collecting data from 6 different wind turbine manufacturers and 20+ sites
- ~10 years of PI historical data
- All PI Vision displays based on AF models

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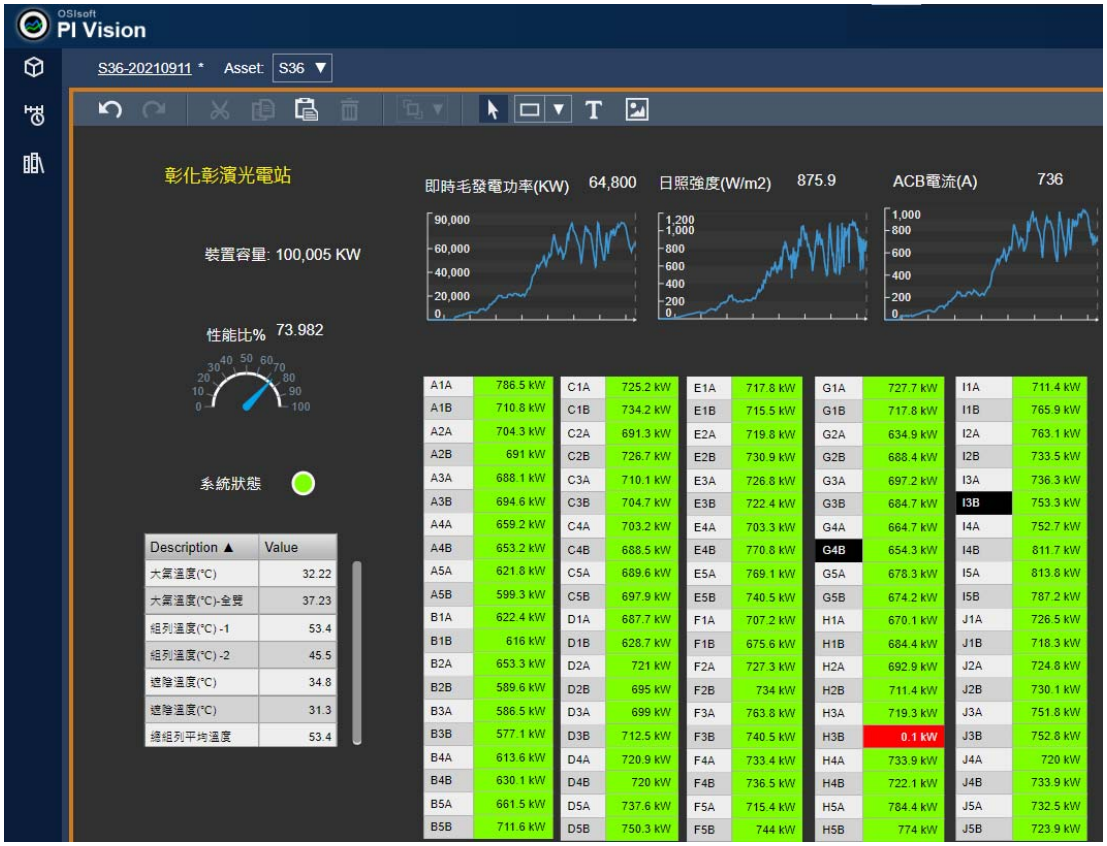
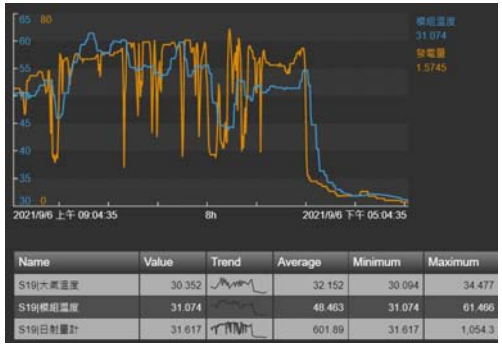
Dep. of Renewable PI System for Solar Generation

Solar Farm Real-Time Monitoring and Operations

- Collecting data from 20+ sites
- 6+ years of PI historical data

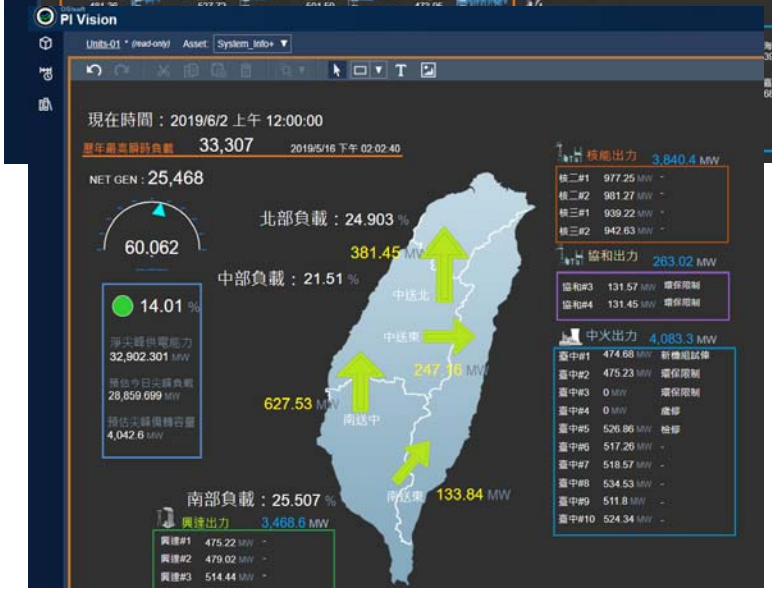


Asset	大氣溫度	日射量計	發電量
S16	3,277	432.48	32.19
S17	29.526312	444.89	461.02
S18	29.702667	458.51	116.93
S19	31.509	380.05	28.438
S20	34.508297	347.25	444.09
S21	35.2473793	357.8	482.52
S22	31.316	436.06	202.39
S23	29.388	44.843	31.247
S24	33	419.46	813.38
S25	30.24	3.753	34.061
S26	-9,999	329.25	39.876
S27	30.923	426.72	73.177
S28	31.912	6,755.4	66.827
S29	-9,999	432.06	88.508
S30	snapfix	snapfix	0



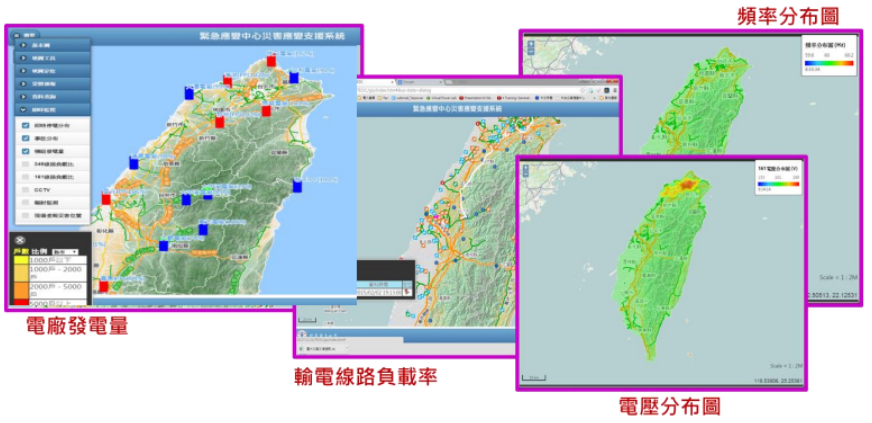
Emergency Operations Center (EOC) PI System

A state-of-the-art EOC – Division of Dept. of System Operations



Through data collection, integration, correlation, analysis and visualization to support…

- Response and recovery management
- Natural disasters or critical events
- Coordinated internal and external communication
- Customer services
- Executive level decision making



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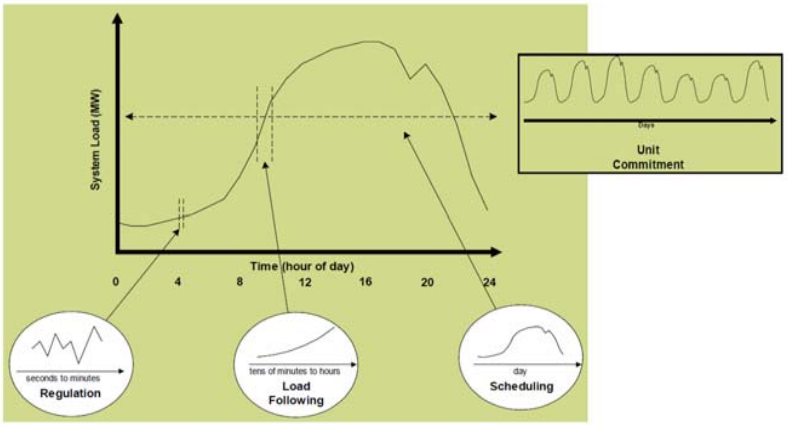
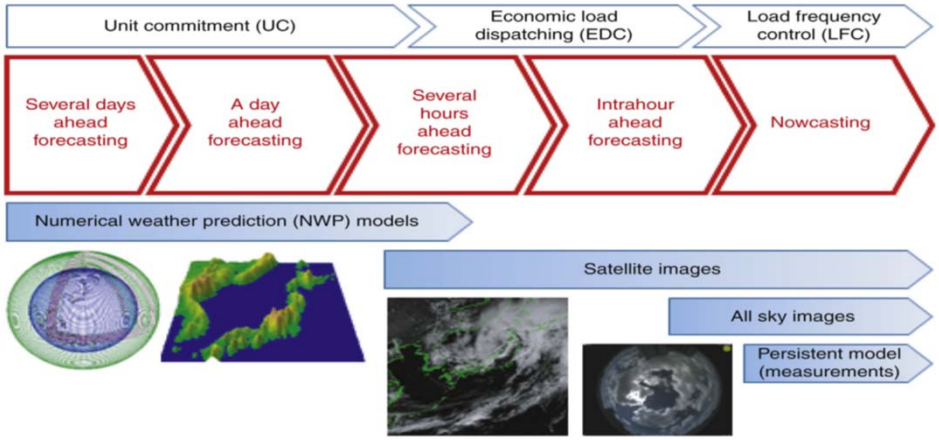
Variable Renewable Energy (VRE) Forecasting

With Different Time Horizons, Methods and Applications in System Operations



<Chaturvedi, D. K. (2016). Solar Power Forecasting: A Review. International Journal of Computer Applications, 145(6)>

Type of Forecast	Time Horizon	Methods	Key Applications
Intra-hour	5-60mins	Largely statistical, driven by recent measurements	**Regulation**, real-time dispatch decisions
Short term	**1-6 hours ahead**	**Blend of statistical, NWP models**	**Load-following,** next-operating-hour unit commitment
Medium term	**Day-ahead to 1 week ahead**	**Mainly NWP with corrections for systematic biases**	**Unit commitment and scheduling,** market trading
Long term	1 week to 1 year, Seasonal	Based largely on analysis of cyclical patterns	Resource planning, contingency analysis



<Photovoltaic and Solar Forecasting State of the Art, REPORT PVPS T14 01/2013>

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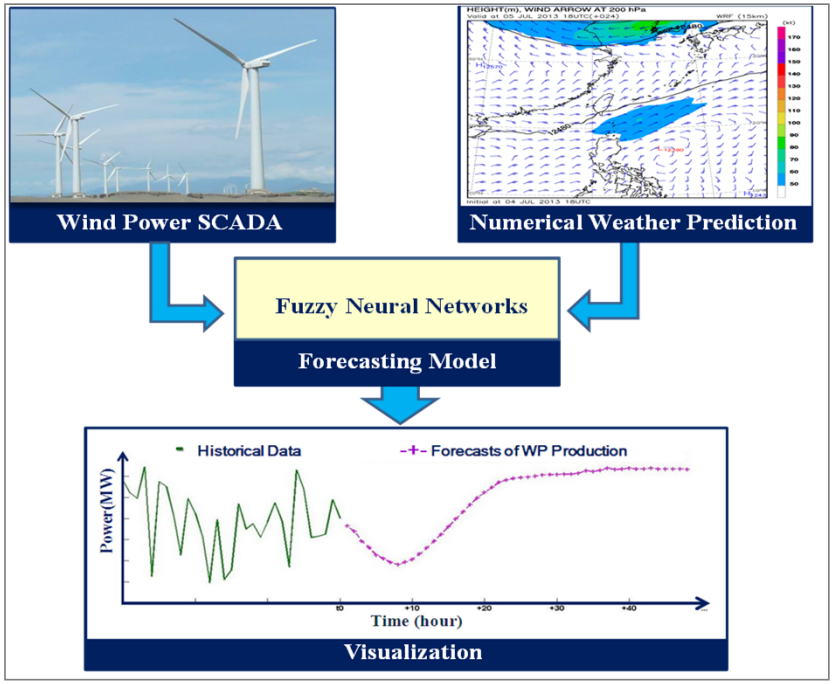
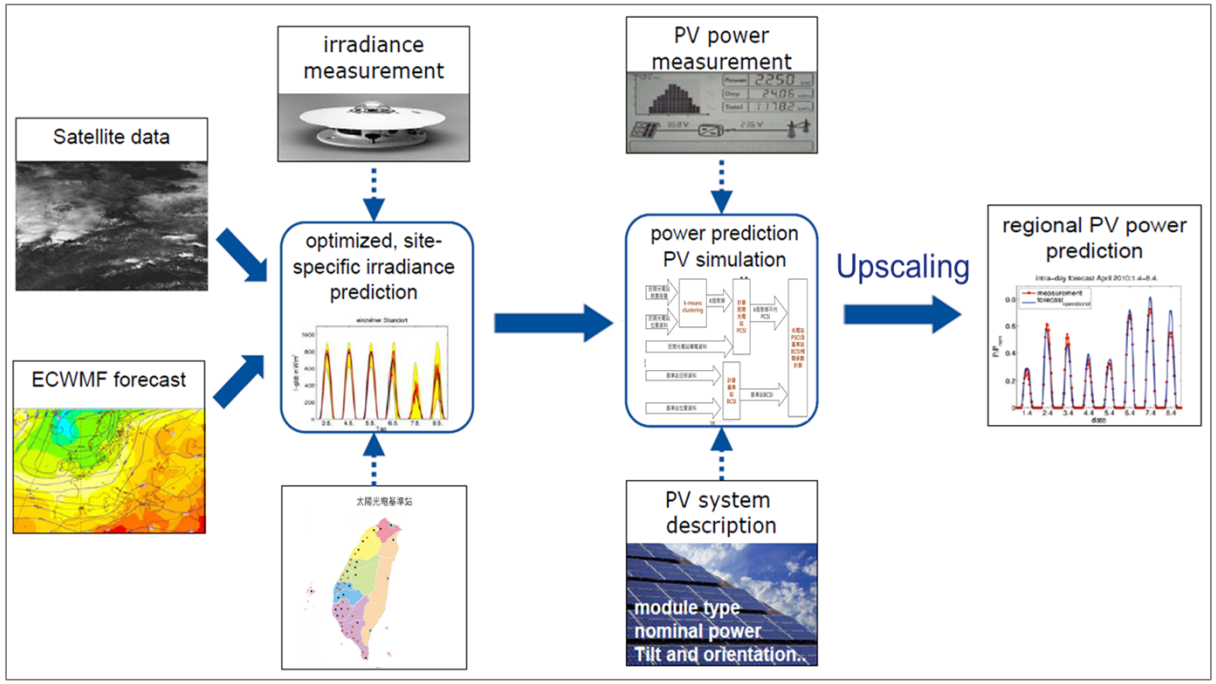
Renewable Forecast System Development

System Overview

Wind Farm



Solar Farm



<Elke Lorenz, Elke Lorenz,Jan Kühnert, Detlev Heinemann, "PV Power Prediction in Germany " IEA PVPS Task 14 workshop, Kassel,8/5/2012>

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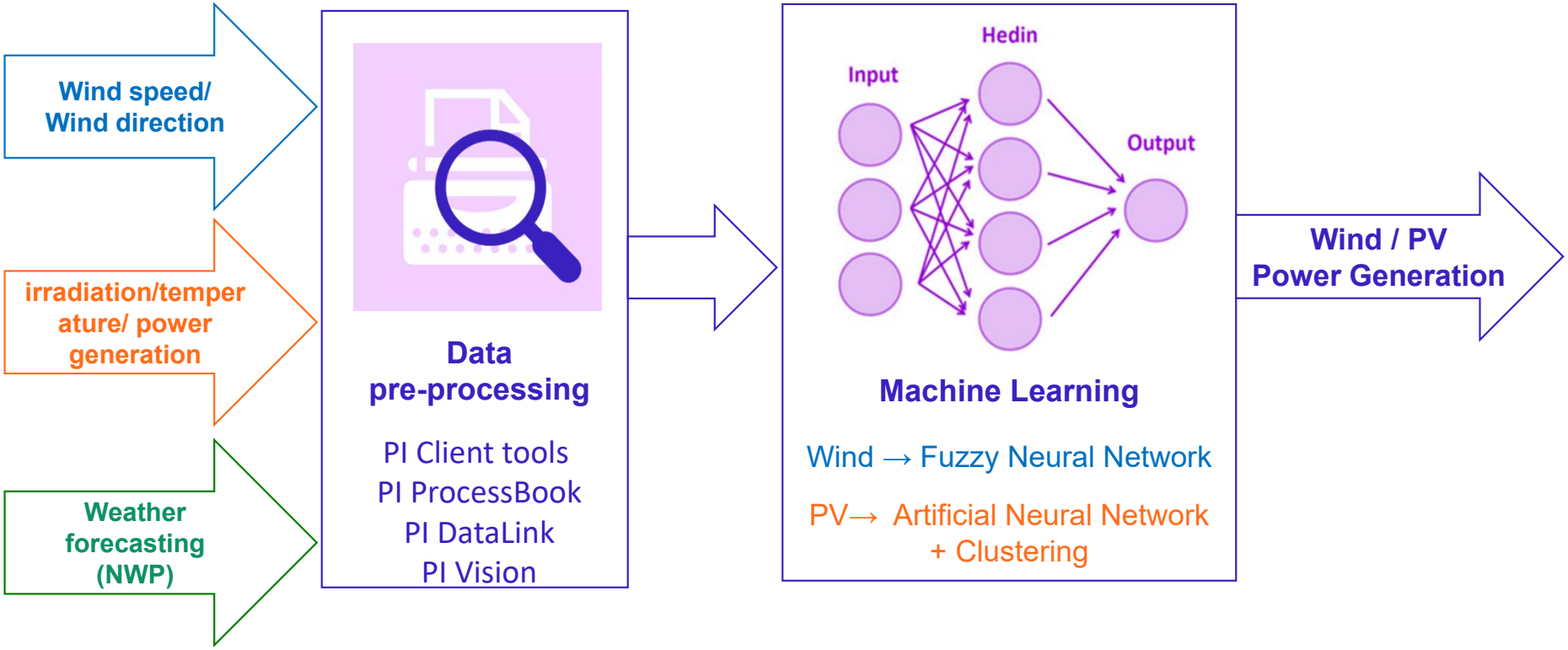
Forecast Model – Neural Network



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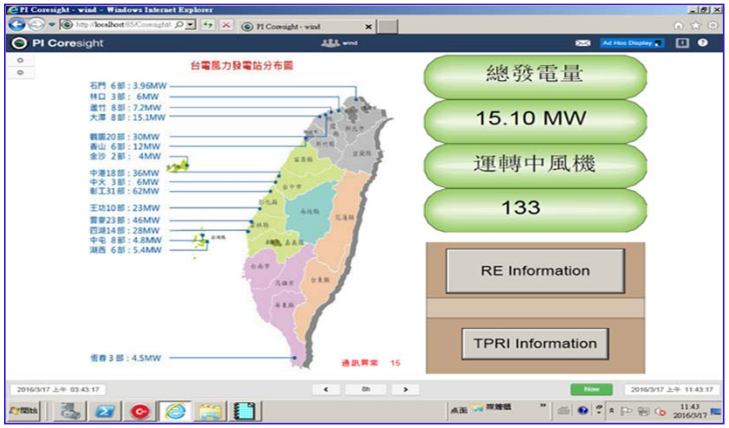
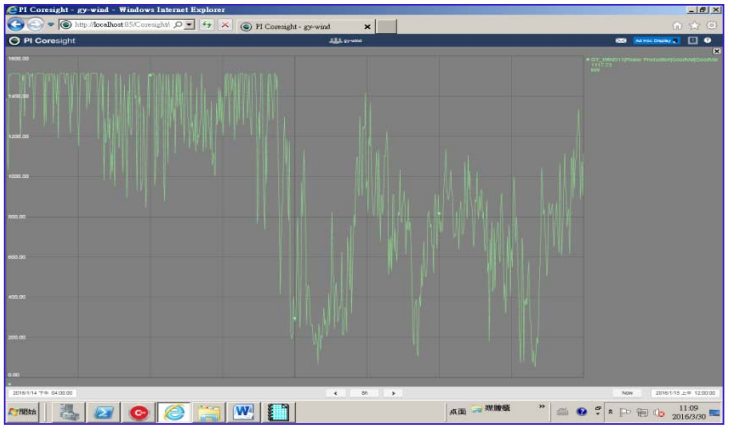
Analyzing Data to Support Wind Forecasting

Wind Farm Monitoring and Data Analysis





~10 years of PI historical data

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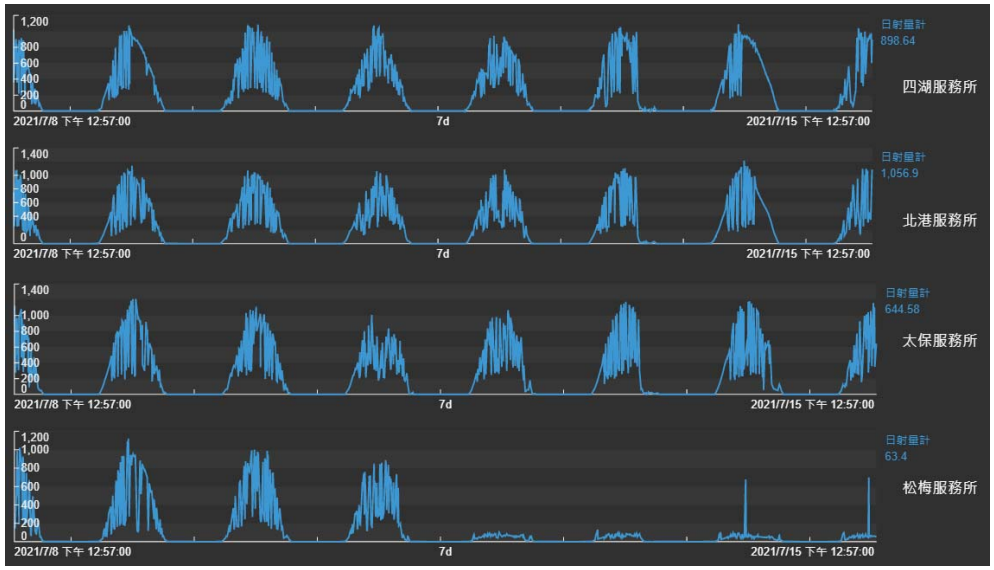
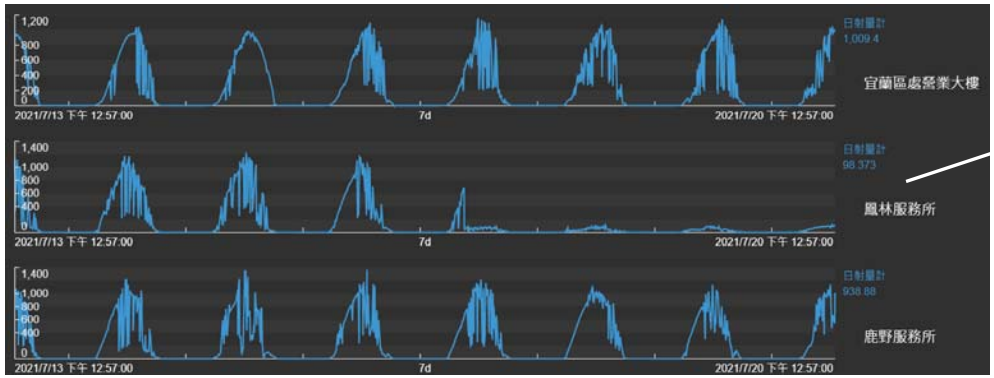
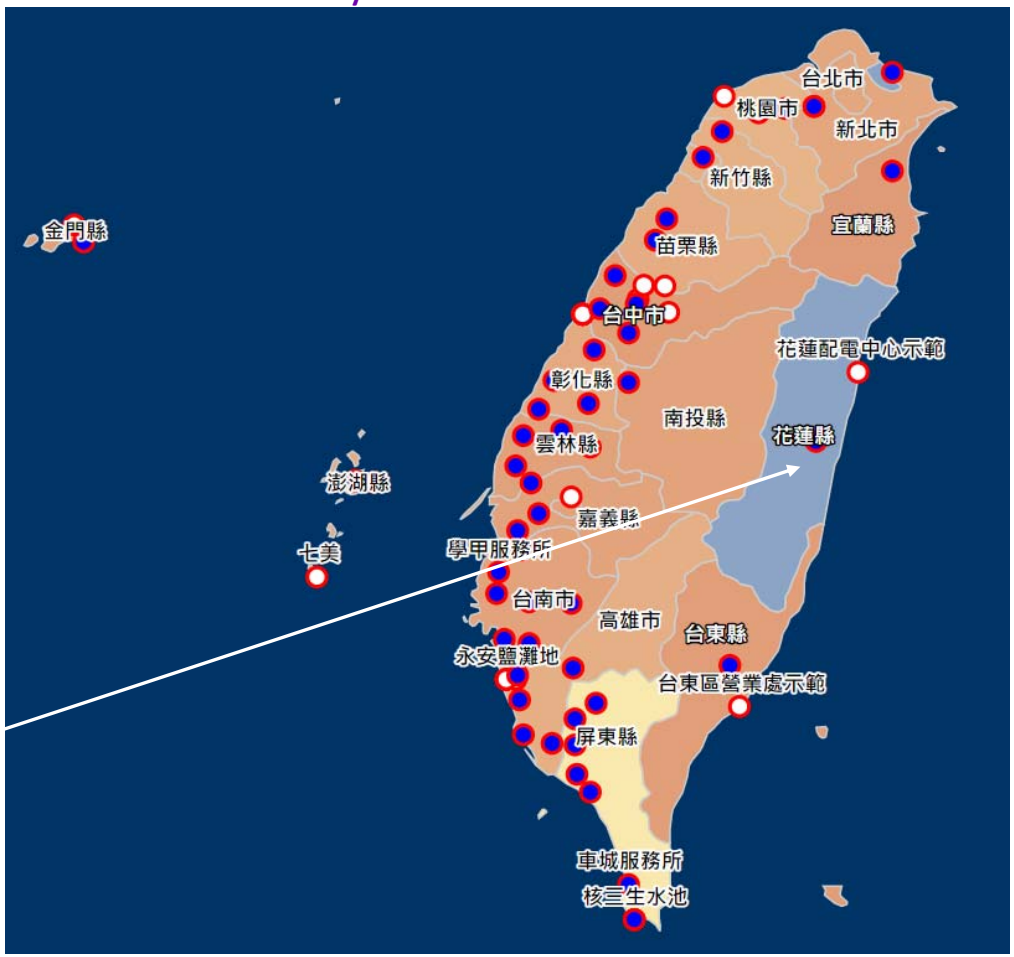
Analyzing Data to Support Solar Forecasting

Solar Monitoring and Analysis from Pyranometer

~3 years of PI historical data



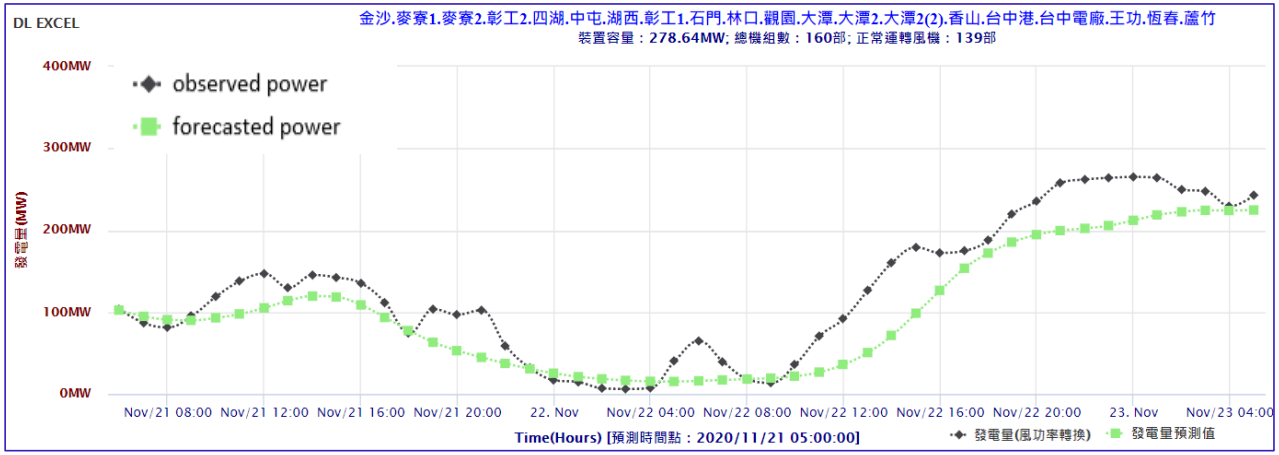




Wind Forecasting

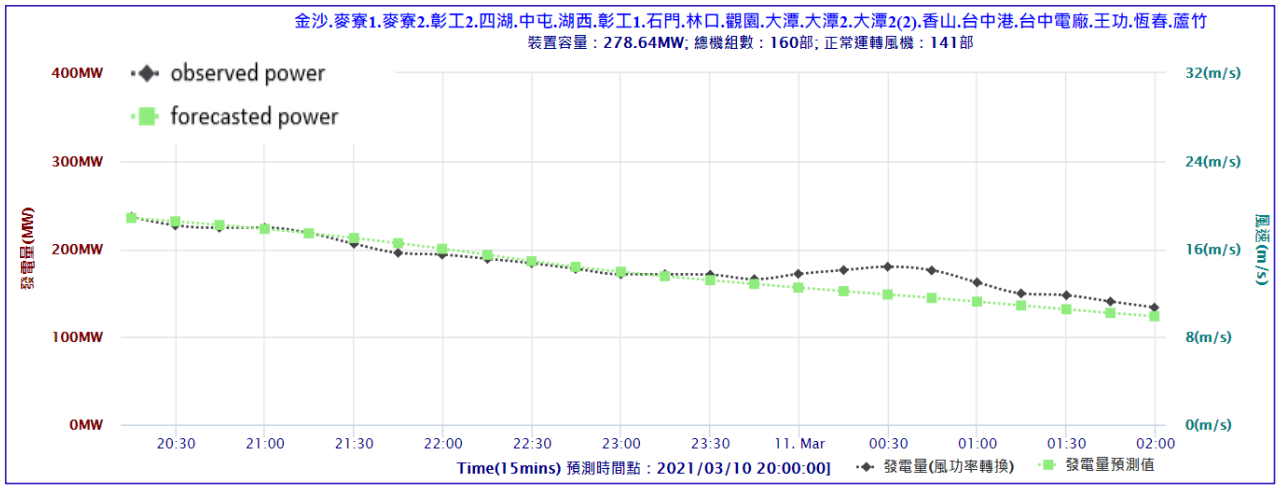
Forecasting length: 1-48 hour

Forecasting interval: 1 hour



Forecasting length: 0.25-6 hour

Forecasting interval: 15 min



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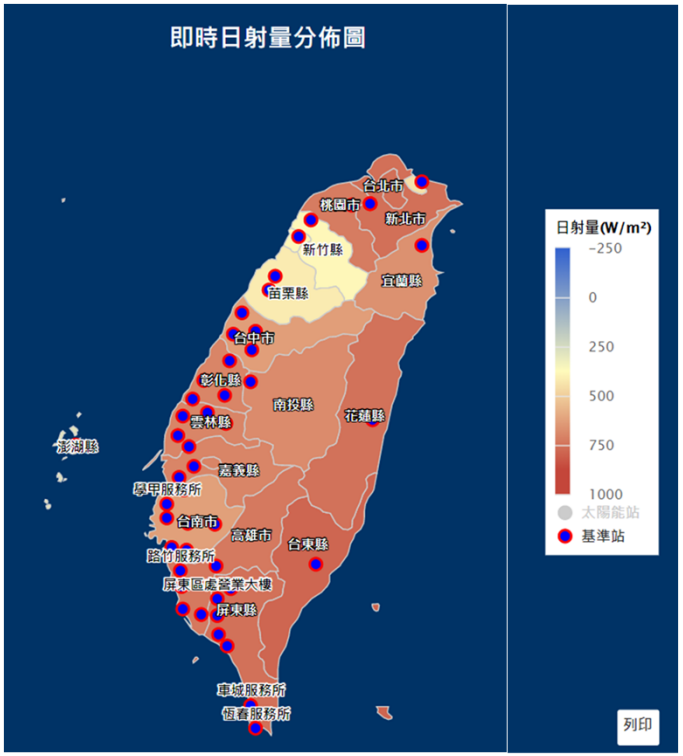
Solar Power Estimating

Real-Time Regional Solar Weather Measurement Data



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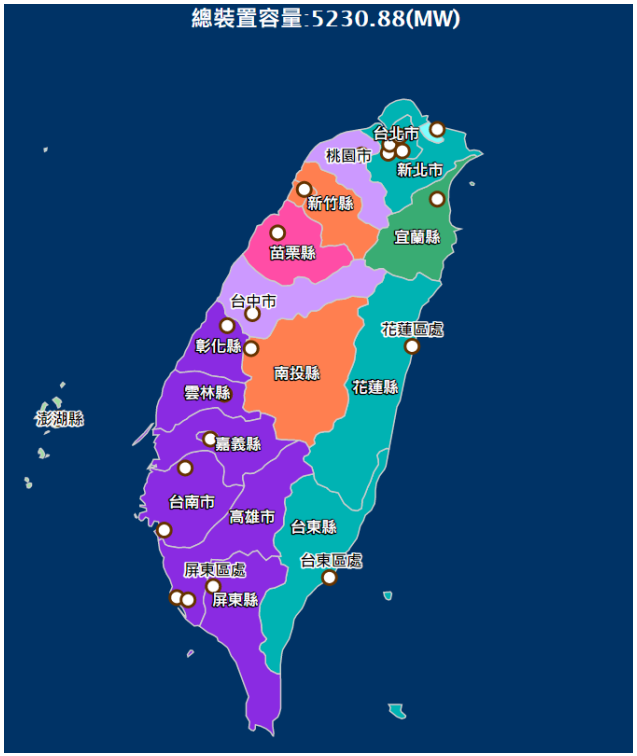
Installed Capacity Data



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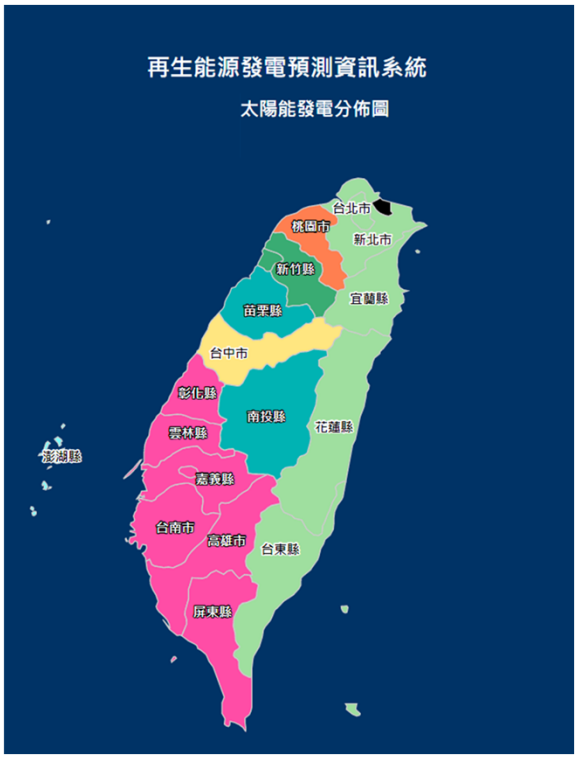
Forecasted Solar Power Generated



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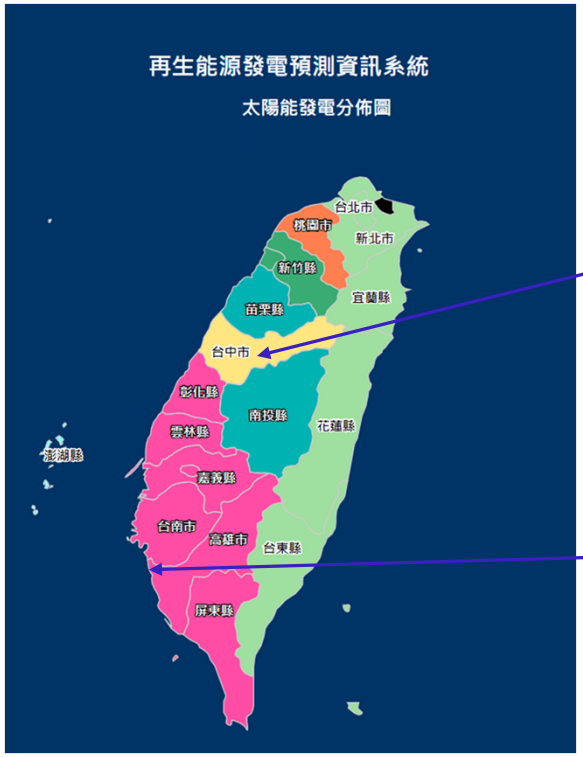
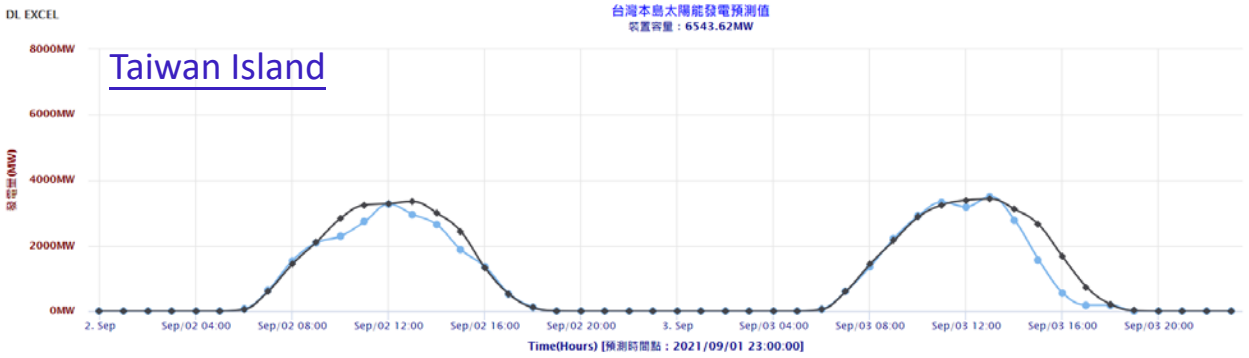
Solar Forecasting

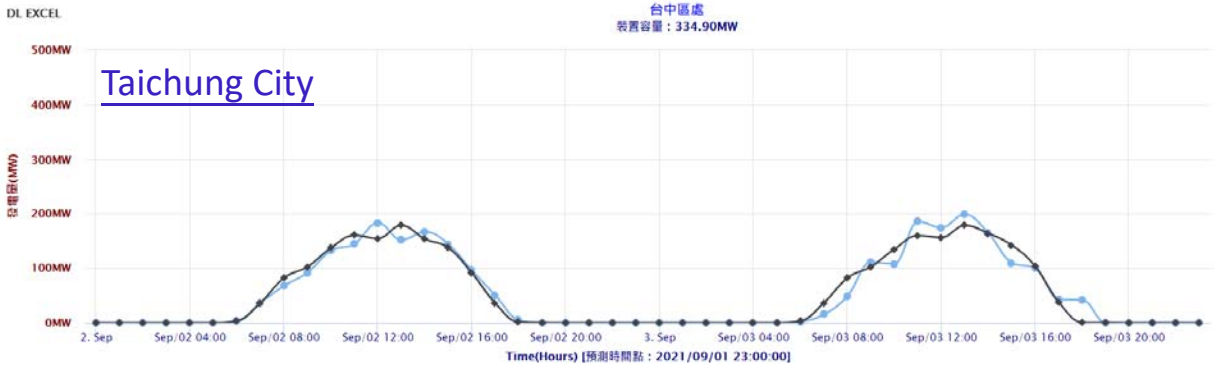
Forecasting length : 1-48 hour
Forecasting interval : 1 hour



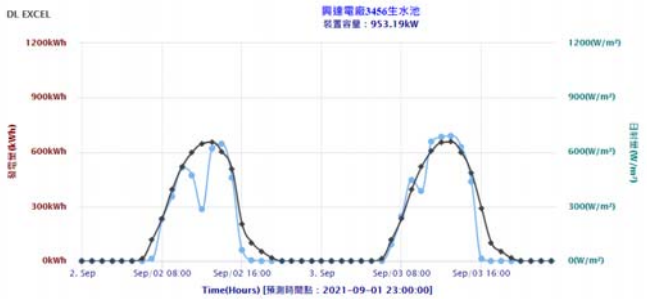
Taiwan Island



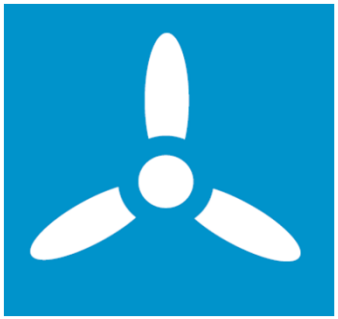
Taichung City



Xingda PV Site



Wind Power Forecasting Error



NMAE%	Hour Ahead	Day Ahead
TPC wind farms	3.5~10%	4~25%
Average error	～6.5%	～14%

Solar Forecasting Error for PV power plants

NMAE%	PV sites for Renewable Department
Hour Ahead	3 ~11%
Day Ahead	4 ~14%

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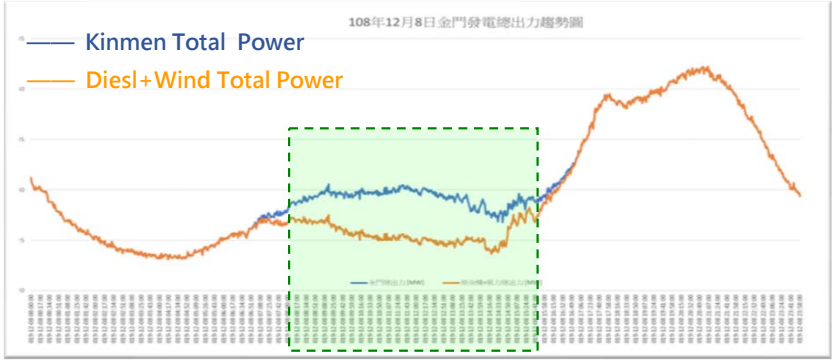
Kinmen Island Existing Renewable Energy Adoption and Mix

Aiming for Low-Carbon Island and Sustainable Community for Energy Independence

Renewable energy shared 33.5% at noon on 8th Dec. 2019

	Diesel	Wind	Solar (Estimated)	Renewable total
Power (KW)	15,030	3,662	3,901	7,563
%	66.5	16.2	17.3	33.5



- ✓ 100 miles off the southeastern coast of mainland China across the Taiwan Strait
- ✓ Taiwan Power distribution has a vision of achieving maximal renewable penetration by 2025
- ✓ Currently four distribution substations, peak load ~60MW and 90+% fuel dependency
- ✓ Need better electric power control tools to perform in dynamic and complex electric grid system and bring high % renewable growth

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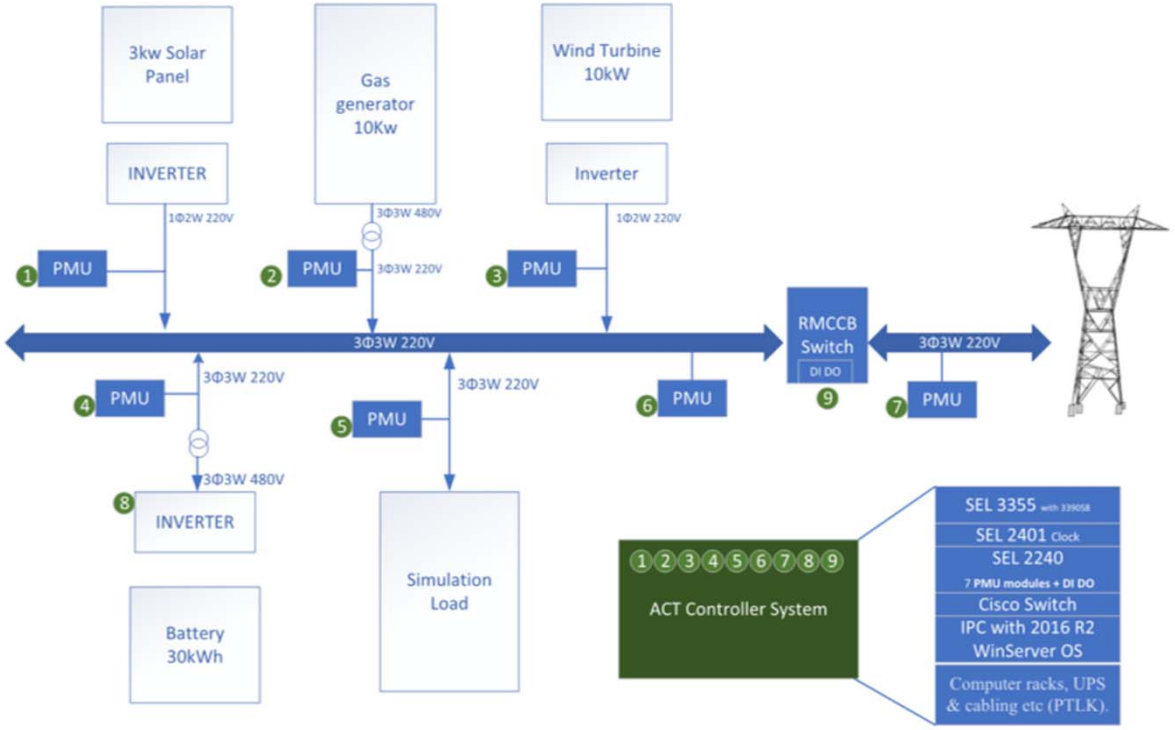
Microgrid Test Bed for Renewables and DER Integration Demonstration

TPRI Partners with PTLK and PXiSE Energy Solutions (with embedded PI System in microgrid solution)



- ✓ Demonstrate synchrophasor-based high-speed and precision control to address intermittencies from renewables
- ✓ Demonstrate mixed energy resources operations without fossil generators
- ✓ Leverage project learning to plan and further increase renewables implementation in Kinmen island

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PI Vision User Interfaces Enable Asset Management and Control

Asset Data

Control UI

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Agenda

- Taiwan Power Company Overview
- Increasing Challenge of Renewables
- PI System in Taiwan Power Company
- Forecasting Renewables, Methods and Results
- Distributed Energy Resources
- Summary

Summary

台灣電力公司

Challenge

- Taiwan Power developed an aggressive plan aiming at upgrading the reliability and quality of power supply, enhancing energy saving and carbon emission reduction, and increasing the penetration of green energy in the grid.

Solution

- Taiwan Power and TPRI deployed PI System as the scalable data platform for renewable wind/solar operations and innovative forecasting systems and now adopted PI System-based distributed energy resource-DER solution for microgrid testbed with battery, solar PV, and load bank integration.
- Deploying microgrid test bed to demonstrate high % of renewables integration and disturbance mitigation.

Benefits

- PI System is the cost-effective data foundation for both operations and R&D to support Taiwan Power's renewable and DER development to achieve energy security, economic development and environmental protection, etc.

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