# Development of Smart Grid in Taiwan and Its Challenges

# 台灣智慧電網發展現況與挑戰

**Faa-Jeng Lin**
Chair, Smart Grid Focus Center, National Energy Program-Phase II, Taiwan
President, Taiwan Smart Grid Industry Association
Chair Professor, Dept. E. E., National Central University, Taiwan

台灣智慧型電網產業協會 Taiwan Smart Grid Industry Association

第二期能源國家型科技計畫 National Energy Program-Phase II

May 12, 2015

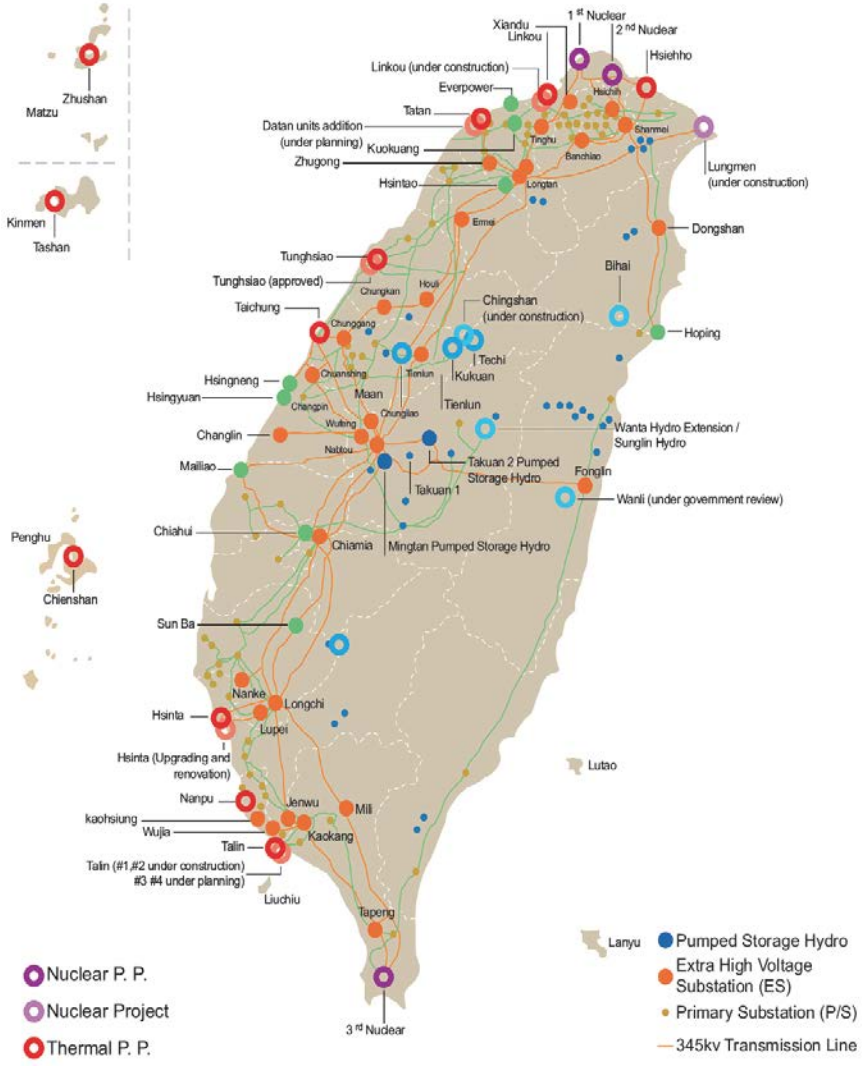
# Outline

- Current Status of Taipower System
- Master Plan of Smart Grid in Taiwan
- National Energy Program - Phases I-II: Smart Grid General Project
- Penghu Smart Grid Demonstration Project, Virtual Power Plant Demonstration Project and AC Microgrid Demonstration Site
- Development of Smart Grid Industry in Taiwan
- Challenges of Smart Grid Development in Taiwan

# Current Status of Taipower System

# Power System in Taiwan

## TPC Power System




Installed Capacity in Year 2013: **41,181** MW

| | Installed Capacity | MW | % |
|---|---|---|---|
| Taipower | Nuclear | 5,144 | 12.45 |
| | Thermal | 22,132 | 53.80 |
| | **Oil** | **3,325** | **8.00** |
| | **Coal** | **8,200** | **21.30** |
| | **LNG** | **10,607** | **25.60** |
| | Hydro | 4,353.60 | 10.5 |
| | **Convential Hydro** | **1,792** | **4.20** |
| | **Pumped storage Hydro** | **2,602** | **6.30** |
| | Wind | 287 | 0.70 |
| | PV | 18 | 0.01 |
| **Subtotal of Taipower** | | 32,508.06 | 78.50 |
| IPP | **Thermal** | 7,707.10 | 18.60 |
| | **Coal** | **3,097.1** | **7.50** |
| | **LNG** | **4,610.0** | **11.20** |
| | **Hydro** | 289.10 | 0.70 |
| | **Wind** | 236.10 | 0.57 |
| | **PV** | 350 | 0.85 |
| | **CoGeneration** | 622.00 | 1.50 |
| **Subtotal of IPP** | | 8,892.60 | 21.5 |
| **Total Installed Capacity** | | 41,181 | 100 |

| Substation | No. | MVA |
|---|---|---|
| EHV | 29 | 56000 |
| Primary | 264 | 68450 |
| Secondary | 295 | 20728 |

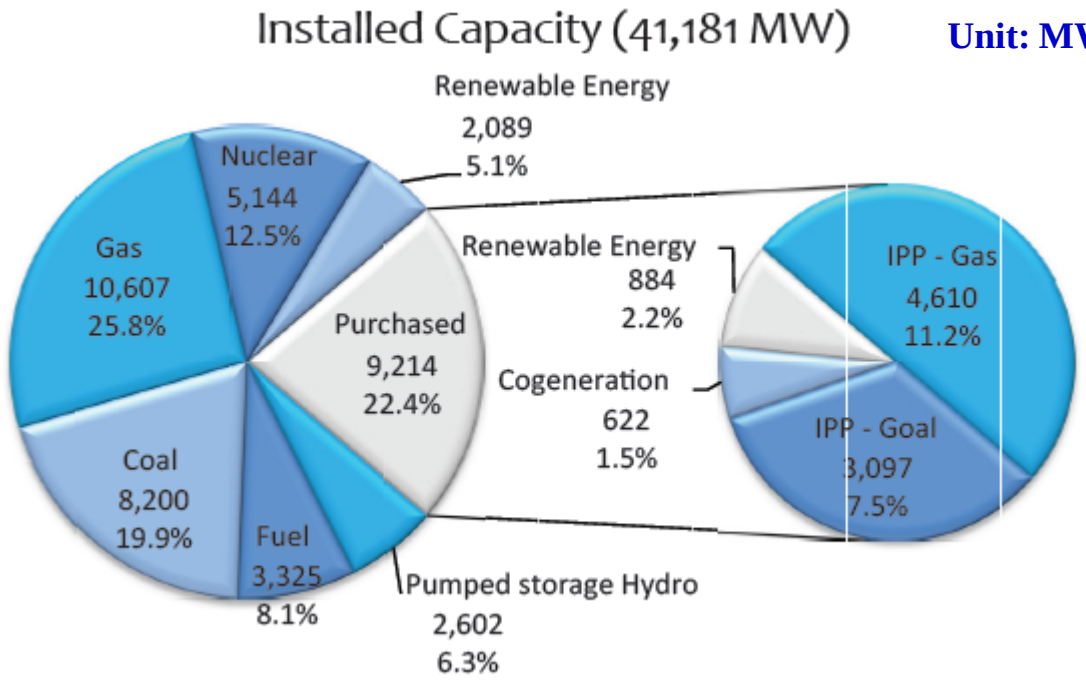
| | ckt-km |
|---|---|
| Transmission Lines | 17,054 |
| Distribution Lines | 351,474 |

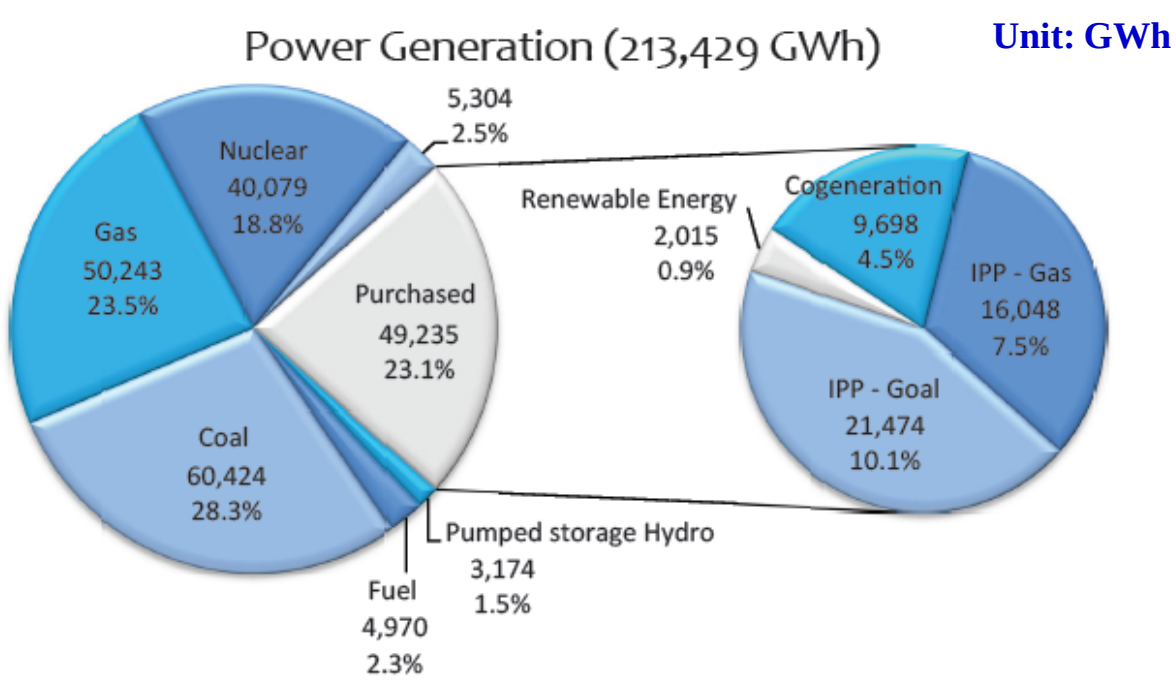
Reference： Taipower www.taipower.com.tw

# Power System in Taiwan

## Taiwan Power Profile

Installed Capacity and Generation Data as of **2013**

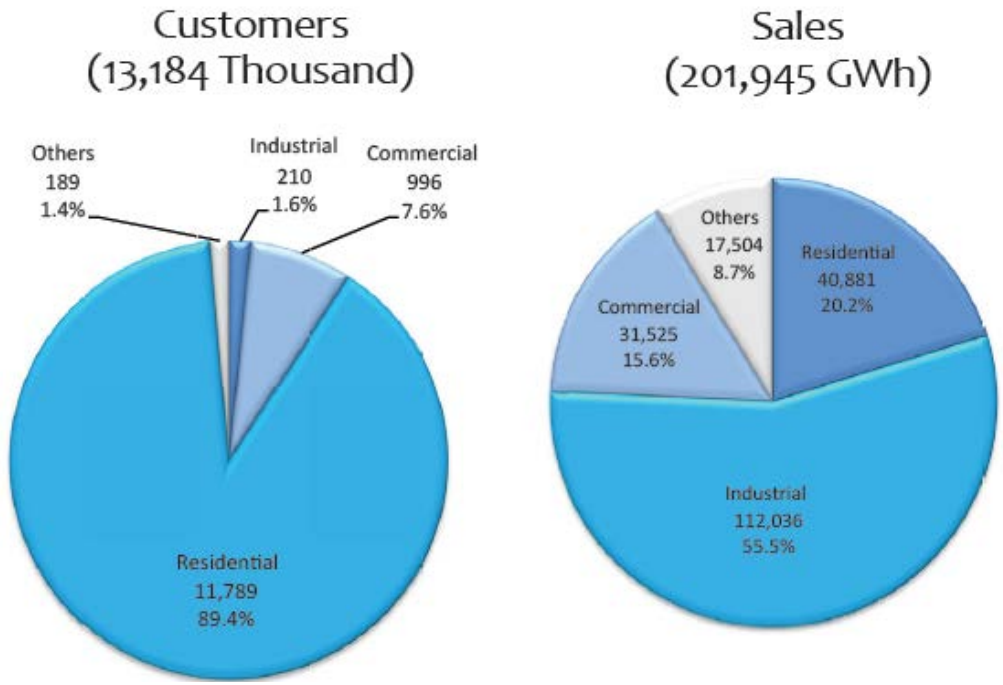



Peak Load in Year **2014**: **34,821MW**

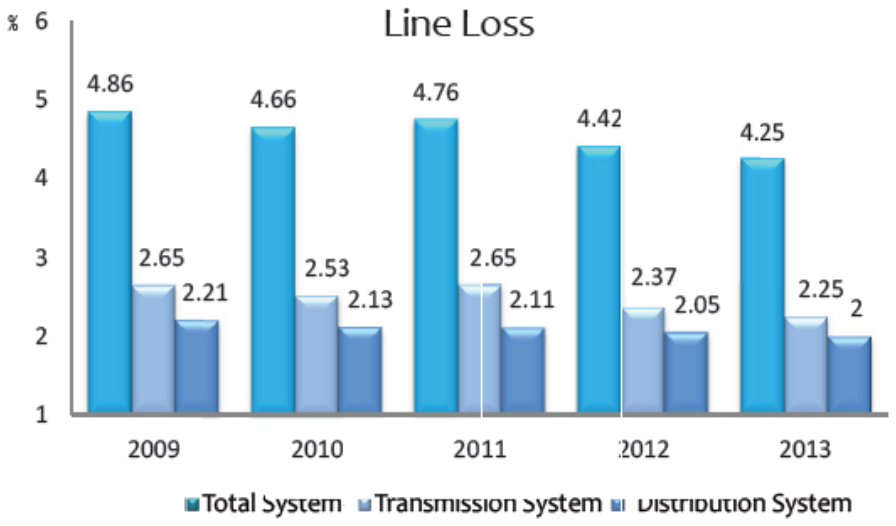
Reference： Taipower www.taipower.com.tw

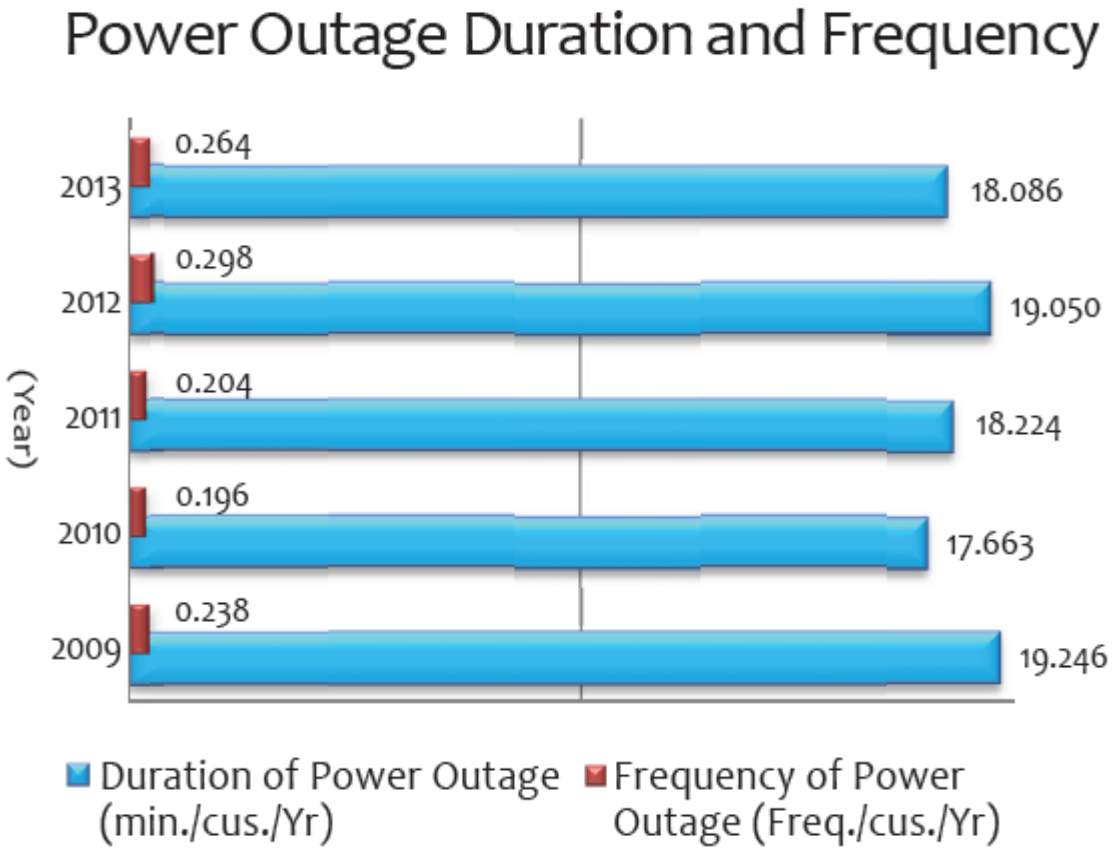
# User Profile of Taipower in 2013









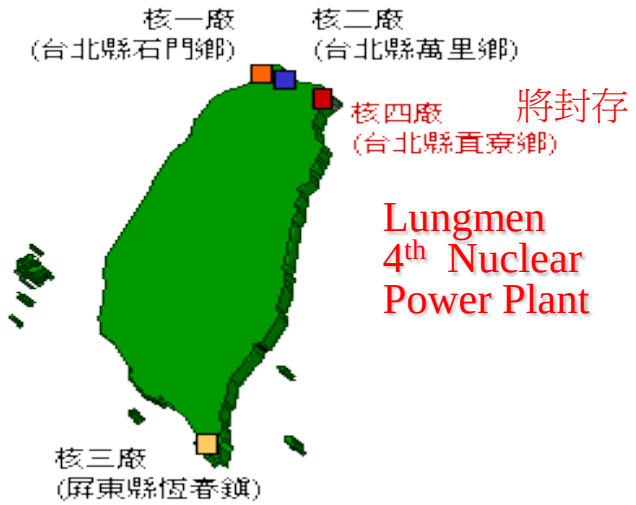
# Nuclear Power Plants in Taiwan

## ■ Nuclear Power Plants in Taiwan

| Station | Set | Capacity (MW) | Status |
|---|---|---|---|
| 1st Jinshan Nuclear Power Plant | 1 | 636 | Retire in 2018 |
| | 2 | 636 | Retire in 2019 |
| 2nd Kuosheng Nuclear Power Plant | 1 | 985 | Retire in 2021 |
| | 2 | 985 | Retire in 2023 |
| 3rd Maanshan Nuclear Power Plant | 1 | 951 | Retire in 2024 |
| | 2 | 951 | Retire in 2024 |
| 4th Lungmen Nuclear Power Plant | 1 | 1350 | Operate after 2017? |
| | 2 | 1350 | Operate after 2018? |

Jinshan
1st Nuclear Power Plant

Kuosheng
2nd Nuclear Power Plant



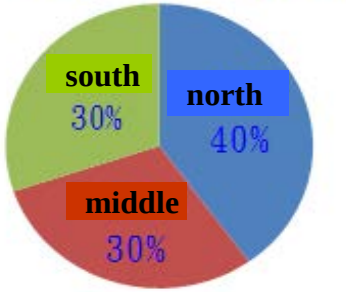

Lungmen
4th Nuclear Power Plant

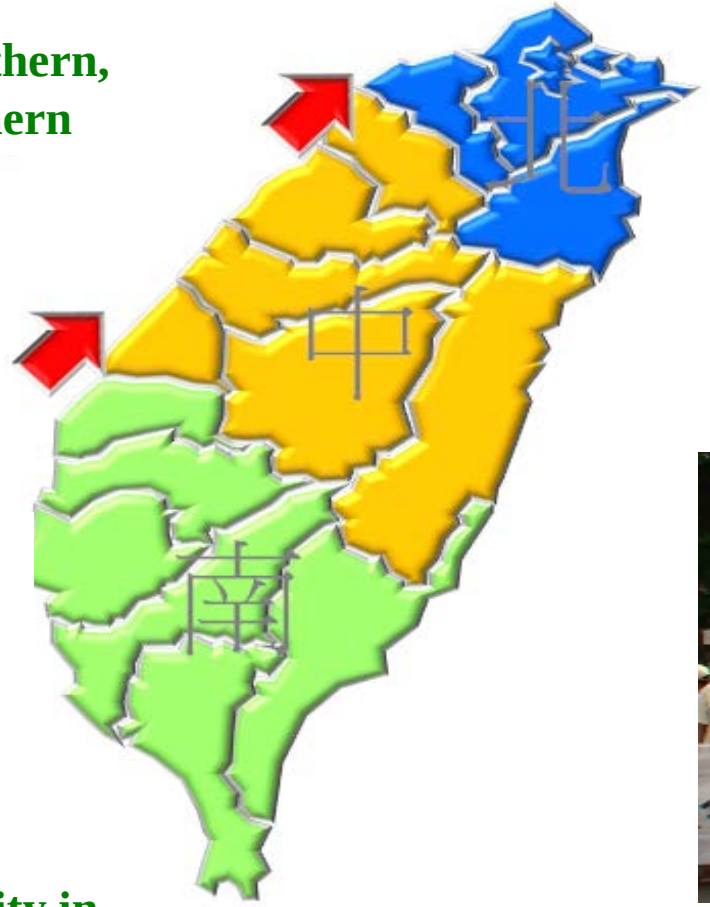
Maanshan
3rd Nuclear Power Plant

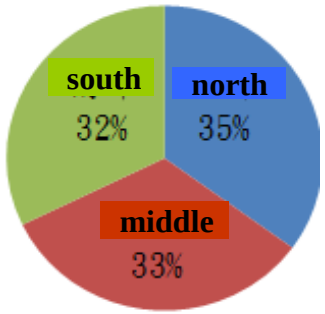
# Regional Power Congestion

## The regional supply capacity and peak load of northern, middle and southern Taiwan in 2013

**Peak load in northern, middle and southern**






**Power supply capacity in northern, middle and southern**


# Current Status of Taipower and Energy Policy of Taiwan

## (1) Current Status of Taipower

a. Due to an extreme lack of indigenous energy resources, Taiwan relies on imported energy resources for 98% of its needs.

b. Fossil fuels play a major role in the energy supply structure, having a tendency of excessive concentration.

c. As an isolated power system, Taiwan Power network has not yet been connected to other power systems.

d. Taipower is owned by the government. Under the government's policy, flat electricity prices have been failing to reasonably reflect the costs.

## (2) Energy Policy of Taiwan

a. **Steadily Reducing Nuclear Dependency**

   a) No extension to life spans of existing plants, and the decommissioning plan should be launched as planned.

   b) The security of the 4th Nuclear Power Plant must be ensured prior its commercial operation.

b. **Replacing Nuclear with LNG** for **Base Load**

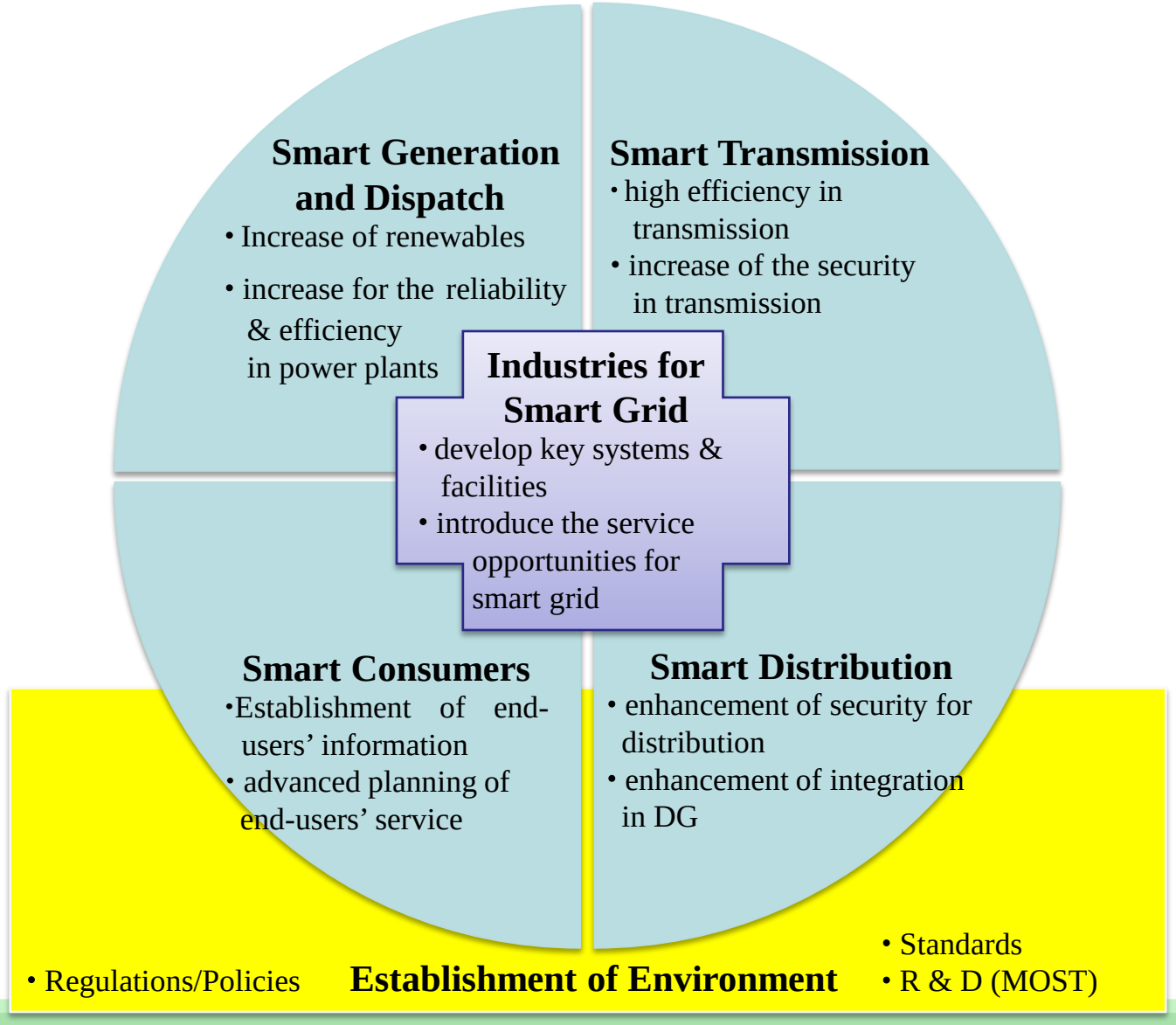
   a) LNG total installation capacity is expected to reach 26,532 MW (accounting for 40% of total capacity of power installations) by 2030.

c. **Promoting Renewable Energy Extensively**

   a) Under the campaign of "one thousand wind mills" and "one million sunshine roofs", the installed capacity of renewable energy is expected to reach 13.75 GW (accounting for 16% of total power installations) by **2030**.

# Master Plan of Smart Grid in Taiwan

# Master Plan of Smart Grid in Taiwan (2011~2030)




**Task Forces：**

- **Ministry of Science and Technology (MOST)**
- **Ministry of Economic Affairs (MOEA)**
  - Bureau of Energy
  - Bureau of Standards
  - Industrial Development Bureau
  - Department of Industrial Technology
- **Taiwan Power Company**
- **Institute for Information Industry**
- **Institute of Nuclear Energy Research**
- **Industrial Technology Research Institute**
- **Taiwan Institute of Economic Research**
- **Taiwan Smart Grid Industry Association**

# Objectives of Smart Grid Master Plan

| Benefit | Objective | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Security & Reliability in power Grid | System average interruption duration index (SAIDI) | 21min/ customer・year | 16min/ customer・year | 15.5min/ customer・year |
| Energy efficiency | Efficiency in thermal power plants | 42.52% | 44.73% | (2023 44.95%) |
| Renewable | Percentage of installed capacities | 4.7% | 20% | 30% |
| Carbon reduction | Carbon Oxide reduction | (CO2 emission: 276 million tons) | 35.99 million tons | 114.71 million tons |

# National Energy Program-Phases I-II:
# Smart Grid General Project

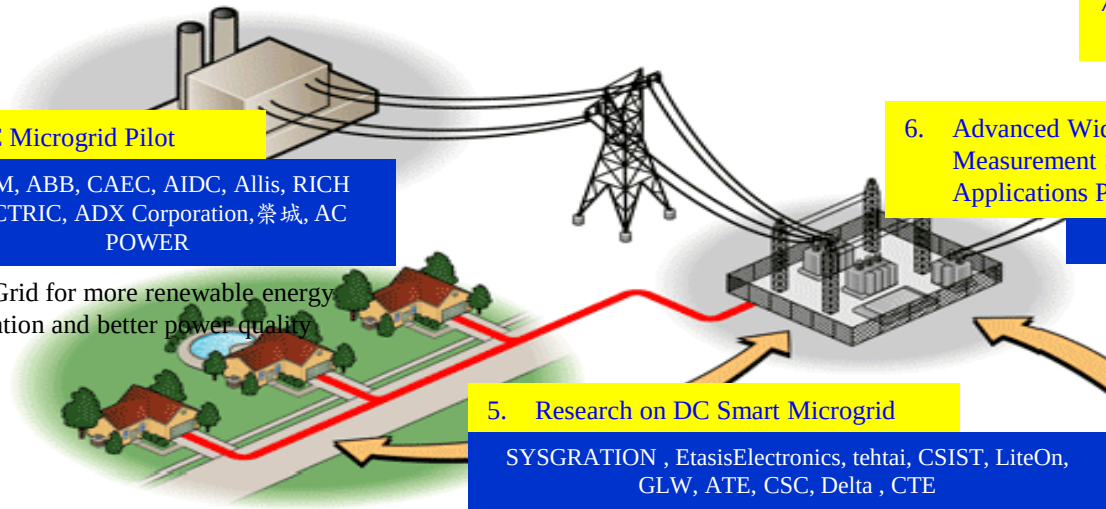
# National Energy Program-Phase I: Smart Grid General Project

**Pilot Projects and Preliminary Collaborating Firms**

1. AC Microgrid Pilot

CHEM, ABB, CAEC, AIDC, Allis, RICH ELECTRIC, ADX Corporation,榮城, AC POWER

MicroGrid for more renewable energy penetration and better power quality



5. Research on DC Smart Microgrid

SYSGRATION , EtasisElectronics, tehtai, CSIST, LiteOn, GLW, ATE, CSC, Delta , CTE

6. Advanced Wide-area Measurement System (WAMS) Applications Pilot Project

ADX, TATUNG

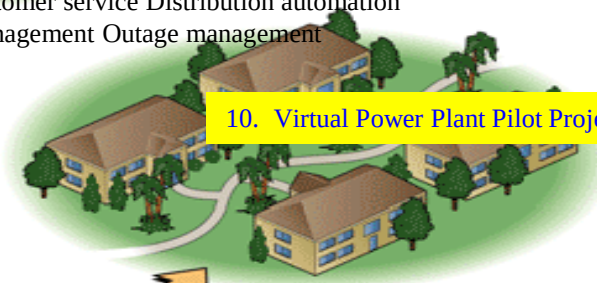
7. Transmission System Power Quality Monitoring and Control Technology Development and Applications Pilot Project

ADX, APPA, TAYA, INER

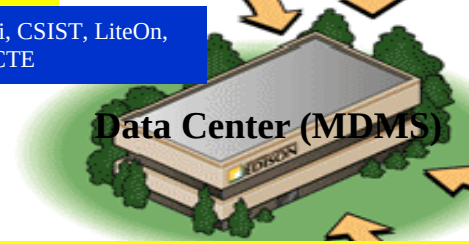
3. Advanced DAS Pilot Project

Hsiang Cheng, Connet, Allis, Ximple

Billing/Customer service Distribution automation
Energy Management Outage management

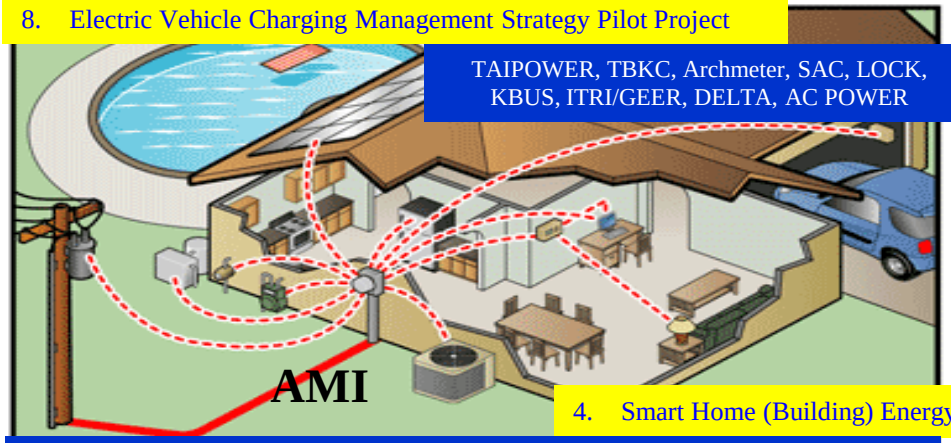


10. Virtual Power Plant Pilot Project




8. Electric Vehicle Charging Management Strategy Pilot Project

TAIPOWER, TBKC, Archmeter, SAC, LOCK, KBUS, ITRI/GEER, DELTA, AC POWER




2. Advanced Metering Infrastructure (AMI) Pilot Project

Tatung, AcBel, Arch Meter, JosephTec, Delta, MOXA

Meter is the interface
between customer loads and energy management systems and the grid

9. Smart Grid And AMI Standard Establishment

CHEM, CHT, DELTA

11. Smart Grid Demo Site in Penghu

4. Smart Home (Building) Energy Management System Pilot Project

NETVOX, Microtime, Panasonic, Megawin, CHTTL, Raydium, SPIROX, ABB, AIRONE, 源鼎, ITRI/GEER, ITRI/IC, III, TATUNG

Improve of building energy efficiency and public energy saving conscious

# Smart Grid General Project - Test Beds

**AMI (Institute for Information Industry)**
National Center University, Taoyuan
(2011~2013)

Advanced Metering Infrastructure (AMI) Enhancement Project

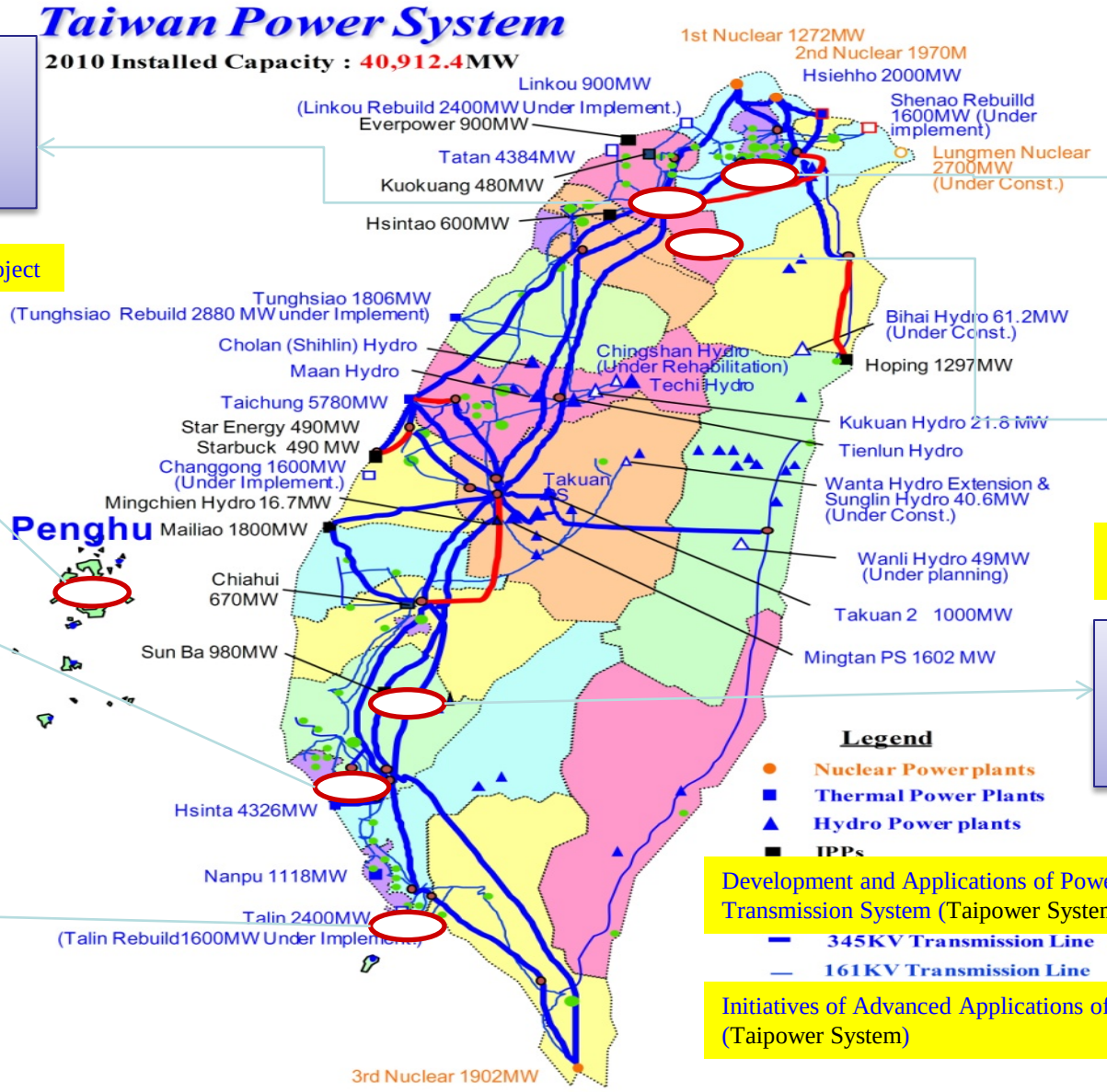
**Smart Grid Demo Site**
National Energy Project – Smart Grid and AMI
(2013~2018)

**Smart Home(Building)EMS**
National Cheng Kung University, Tainan
(2011~2013)

Leading Project on Power Energy Management System of Smart Home (Building)

**EV Charging Stations**
National Sun Yat-sen University, Kaohsiung
(2012~2014)

Pilot Project Strategic Power Supply Management for Electric Vehicle Charging




Advanced DAS pilot project

**Advanced DAS(I-Shou University)**
Taipower Research Institute, Shulin
(2011~2013)

AC Microgrid Pilot Project

**AC Microgrid**
INER, Long Tong
(2011~2013)

Microgrid Pilot Project,
Research on DC Smart Microgrid

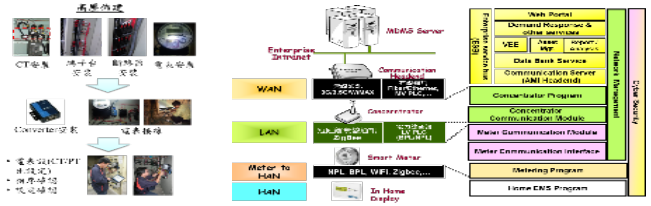
**DC Microgrid**
National Chung Cheng University, Chiayi
(2011~2013)

Development and Applications of Power Quality Monitoring Techniques for Electric Power Transmission System (Taipower System)

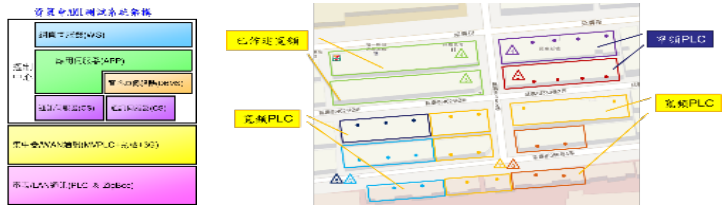
Initiatives of Advanced Applications of Wide-area Measurement System (WAMS) (Taipower System)

# Smart Grid Demo Sites in Taiwan-1

## There are currently 18 Smart Grid Demonstration Sites in Taiwan.

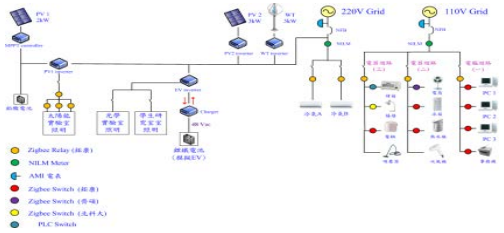


Smart Meter Reading & Demand Response System

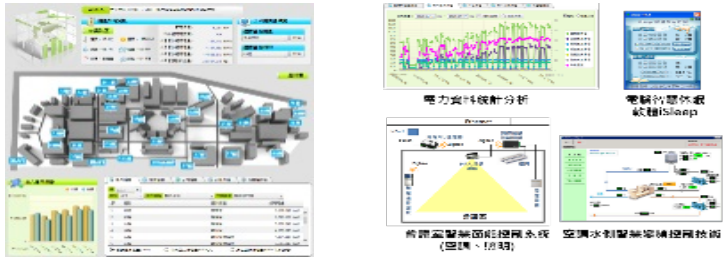


Demonstration of Smart Meter Reading in a Metropolitan Setting

Smart Meter System and Home Energy Management System Demonstration Area



Smart Home (Building) Energy Management System

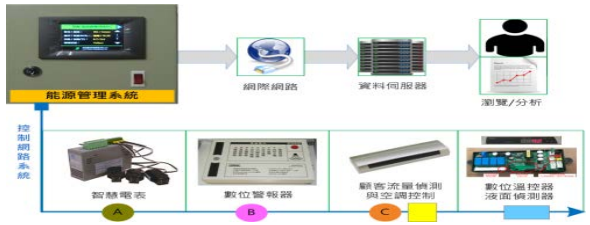


Smart Building Energy Conservation Demonstration Area

Smart Grid Control Center and Smart Home Demo Room


Wastewater Treatment Plant Power Equipment Monitoring and Energy Conservation Management System


Hypermarket Energy Conservation Management System

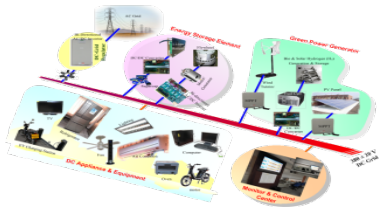



Convenience Store Energy Conservation Management System

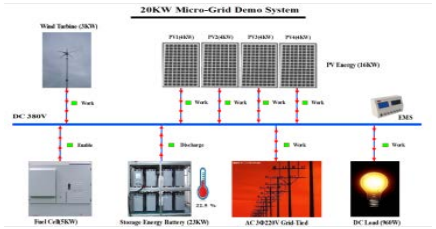
# Smart Grid Demo Sites in Taiwan-2

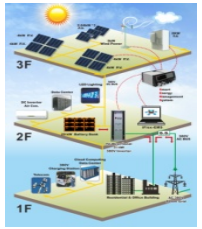

**Advanced Distribution Automation Demo System**


**100 kW Autonomous Micro-grid Demonstration System**

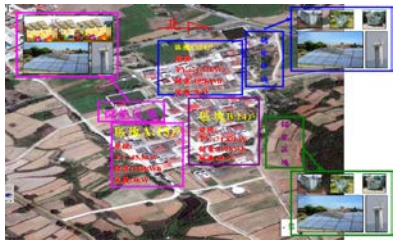
**Smart DC Power System Educational Demonstration House**



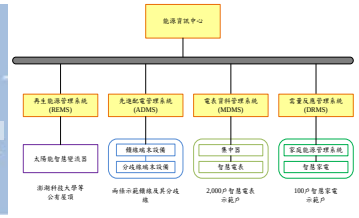



**Smart AC/DC Hybrid Micro-Grid Demonstration System**

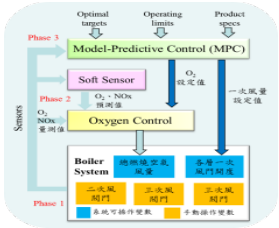

**Micro-grid and Electric Vehicle Demonstration Site**

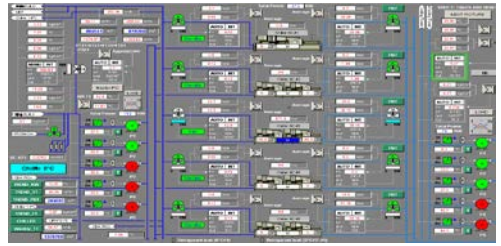
**Dongkeng Smart Grid Demonstration Project**




**Penghu Smart Grid Demonstration Site**


**Furnace Optimized Operation Demonstration System**



**Optimizing Control System for a High-tech Plant Ice Water System**

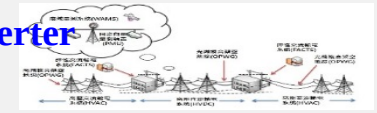
# National Energy Program-Phase II:
# Smart Grid Focus Center Project Framework (2014~ 2018)

sponsored by National Science Council

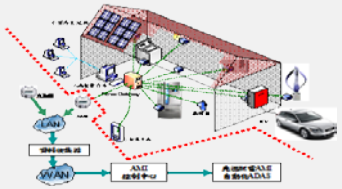
**A** Smart Energy network and energy saving control Technology

**C** Distribution Power Control Technology development

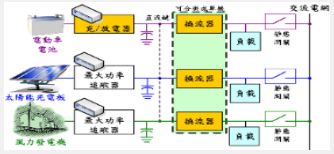
**E** Grid-connected High Power Converter development



**Equipment and system development**



**D** Isolated Microgrid Technology development



**G** Advanced Wide-area Measurement System (WAMS) and control technology

**F** EV charging station manager strategy

**H** Transmission System Power Quality improvement and wheeling technology development

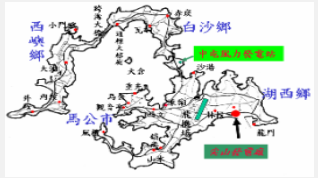
**B** AMI Value-added service and integration technology

**I** Smart Grid and AMI Standard Development

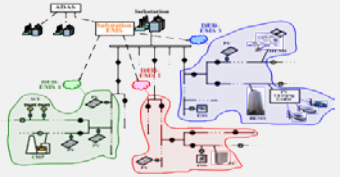
**Technology Commercialization**

**J** Smart Gird Industry Development Project

**Demonstration**




**K** Penghu Smart Grid Demon Site Construction
(Low Carbon Island)



**L** Integrated Applications of Demand Response, Distributed Generator, and Energy Storage System
(VPP Demo Site)

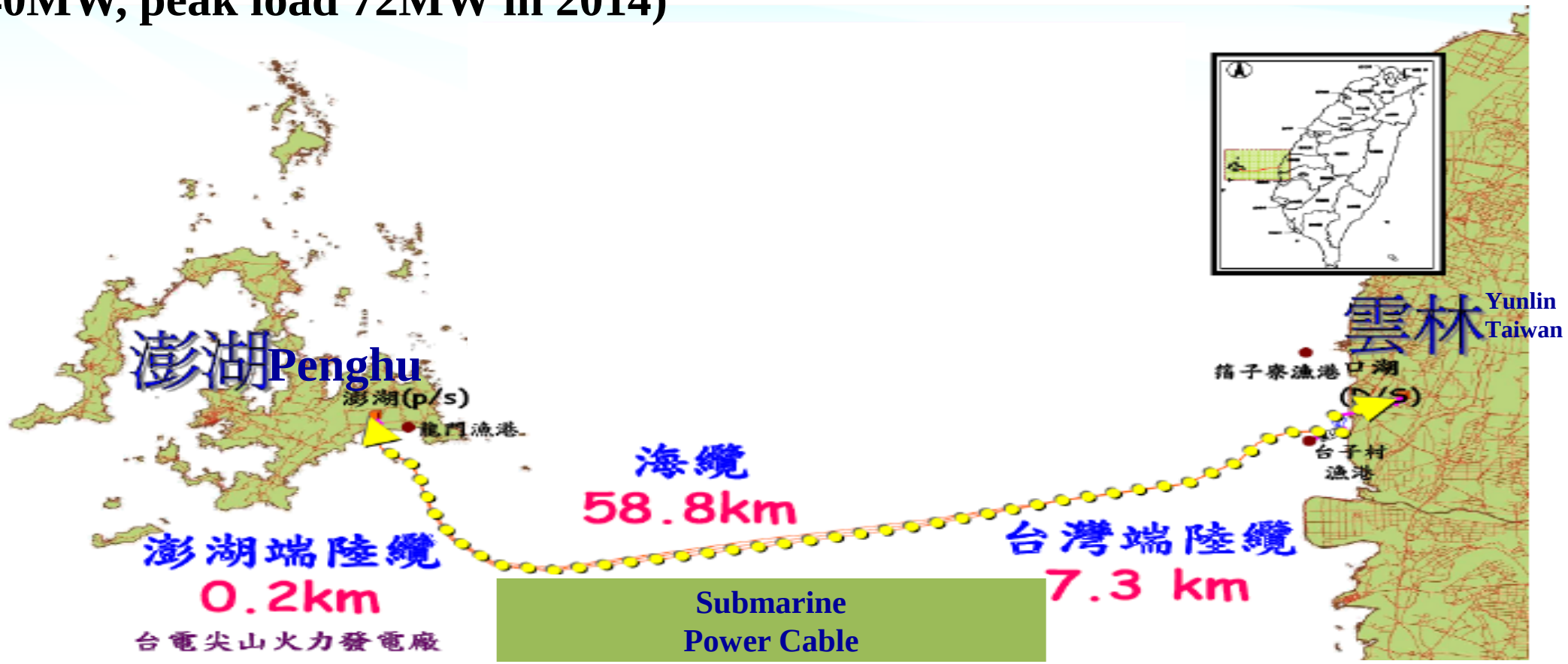
**Implementation**

**M** Taiwan Power Company Smart Grid Installation

# NEP II - Penghu Smart Grid Demonstration Project

# Penghu Smart Grid Demonstration Project

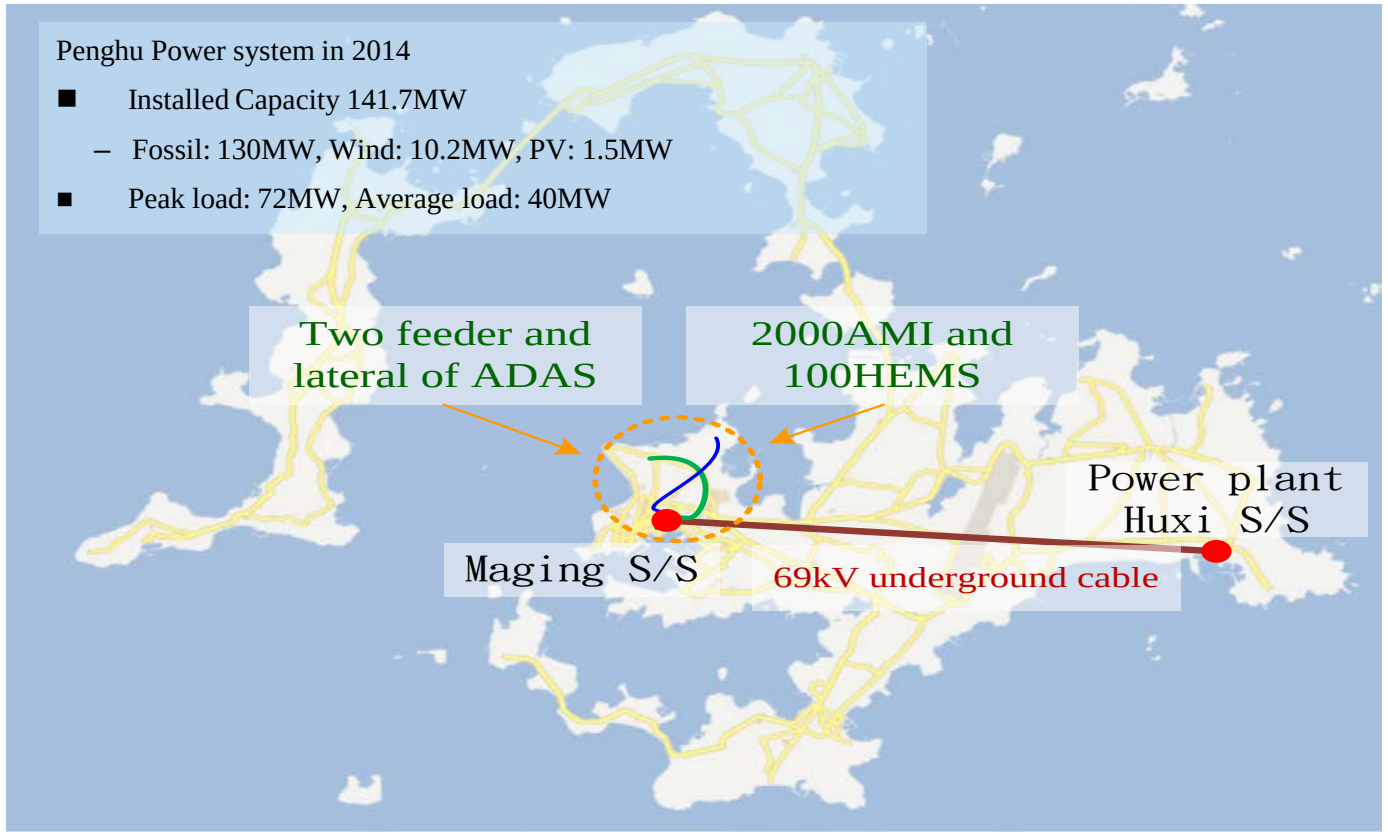
- **Penghu archipelago (48km from Taiwan, inhabitants 100,000, average load 40MW, peak load 72MW in 2014)**




With 161kV/200MW and completed in the end of 2016

# Peng-Hu Smart Grid Demonstration Project

- Smart Grid Master Plan was announced in 2012.
- Some technologies need detailed action plans and technology verification.
- Peng-Hu Island is proposed as the demo site of Smart Grids technologies.

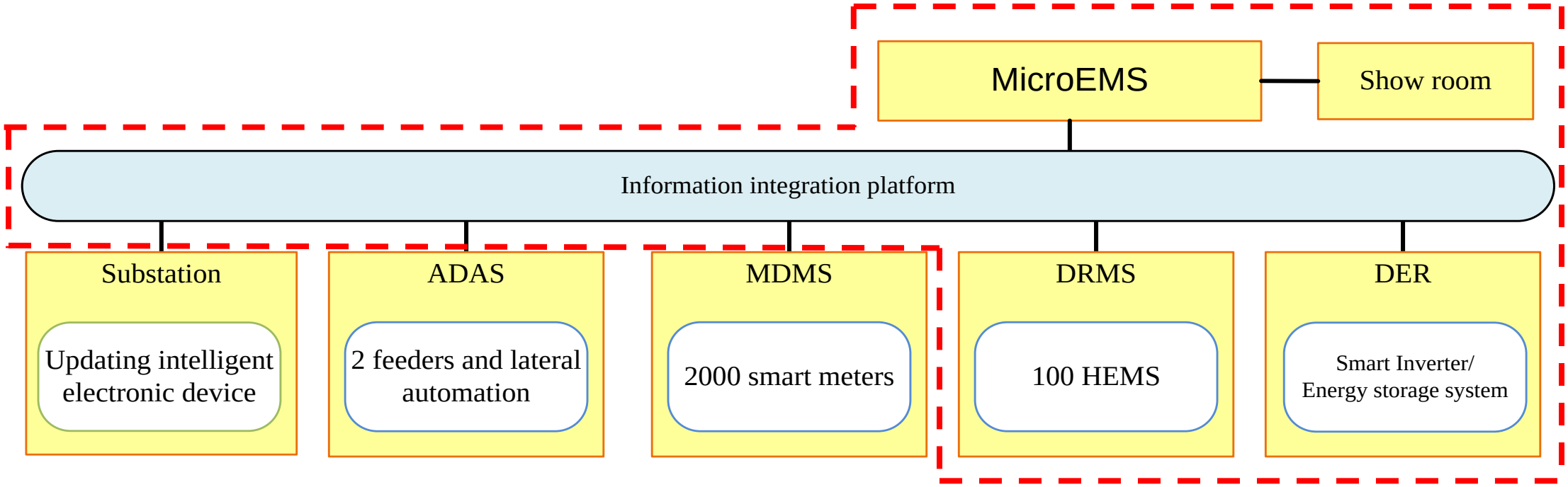



Deployment Items:

1. Smart PV inverter test site
2. Smart Substations (Magong & Huhsi S/S)
3. Advanced DAS with FDIR in two feeders
4. 2,000 smart meters
5. 100 smart users with HEMS
6. Micro-EMS demo system

# Peng-Hu Smart Grid Demonstration Project

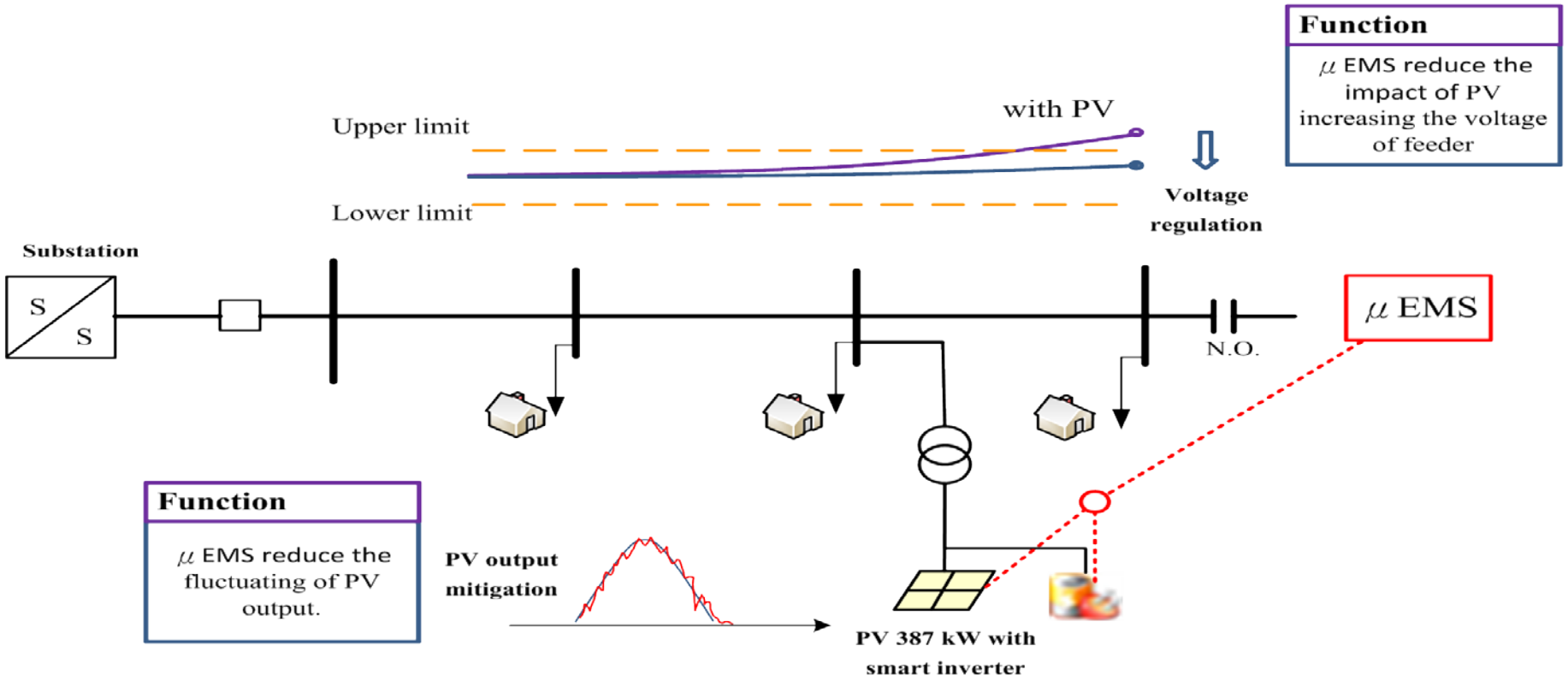
- An information integration platform accesses data with substation, ADAS, MDMS, DRMS and DER through MicroEMS.




ADAS: advanced distribution automation system
MDMS: metering data management system
DER: distributed energy resource

# Peng-Hu Smart Grid Demonstration Project

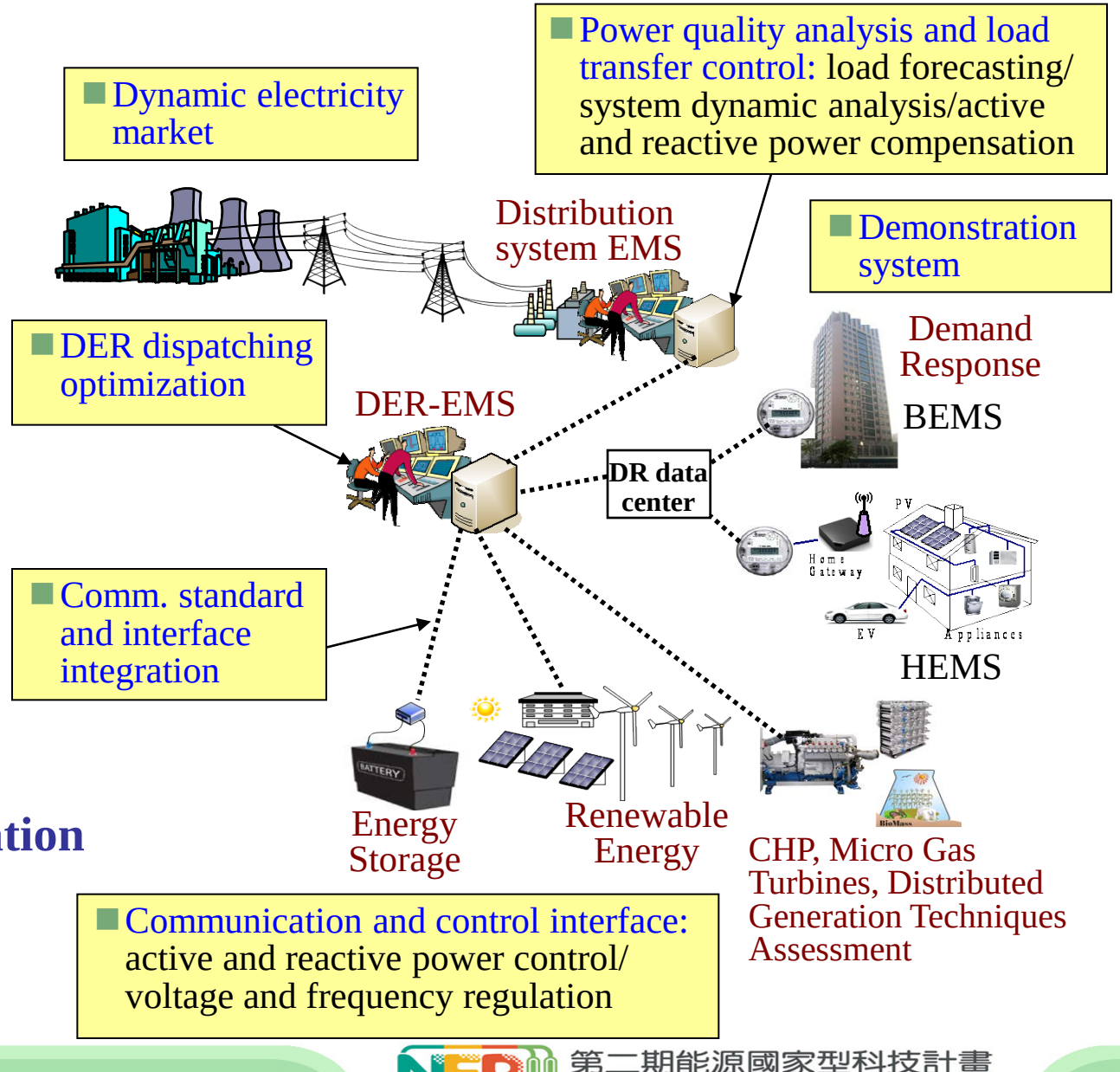
- A micro energy management system (μEMS) can monitor the voltage of feeder and control the DERs (Smart inverter or energy storage system, ESS) to improve the impact of renewable energy (PV).
  - Voltage regulation: reduce the impact of PV increasing the voltage of feeder.
  - PV output mitigation: reduce the fluctuation of PV output.



# NEP II - Virtual Power Plant Demonstration Project

# Virtual Power Plant Demonstration Project

- **Dynamic Electricity Market/Ancillary Services Market Mechanisms**
  - Analyze related international VPP and DR experiences, and propose suitable model for Taiwan
- **Comm. Control Interface Standard**
  - Research and development of comm. Interface
  - CAN Bus / DNP3 / IEC 61850
- **Supervisory Control and Data Acquisition (SCADA)**
  - Software and Hardware Developments
  - Human Machine Interface (HMI)
- **DER Energy Management System (DER-EMS)**
  - Forecasting system, optimal EMS algorithms, reactive and real power demand dispatching
- **Comm. and Control Interface of Energy Conversion System**
- **Distribution System Mathematical Model Simulation**
  - Power system and DER models simulation and analysis
- **Testing System Demonstration**
  - Taiwan Power Research Institute
  - BEMS, DER, and DR integration



# Taipower Research Institute Test Site

## To Build DER-EMS System and Technical Verification

Distributed energy resources

P,Q output control

Power conversion interface

ESS

250kW

Electricity market programs

Substation-EMS economic dispatch decision-making platform

Taipower side

IEC 61850
Advanced DNP

DER-EMS optimal decision-making platform

IEC 61850-7-420
IEEE P2030.2

Power conversion interface

DG

PV, WTG, Diesel generators, Steam turbines

IEC 62056
IEC 61968

Automated demand response (ADR)

AMI

OpenADR 2.0 for ADR

H(B)EMS

H(B)EMS

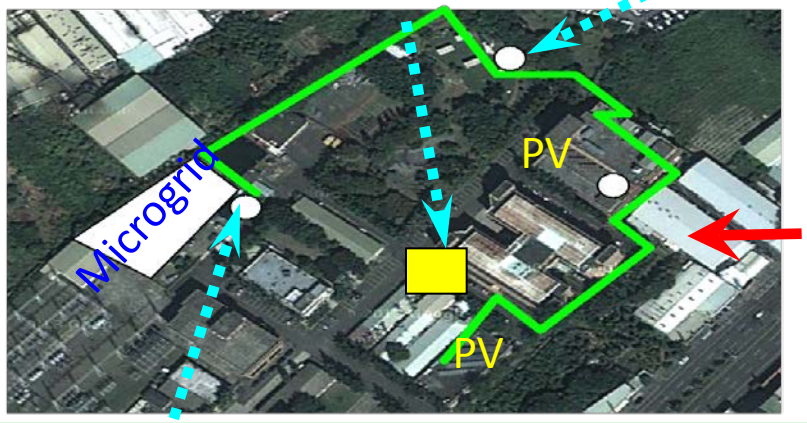
H(B)EMS

DR control
Load saving control

Smart building energy management system

ESS

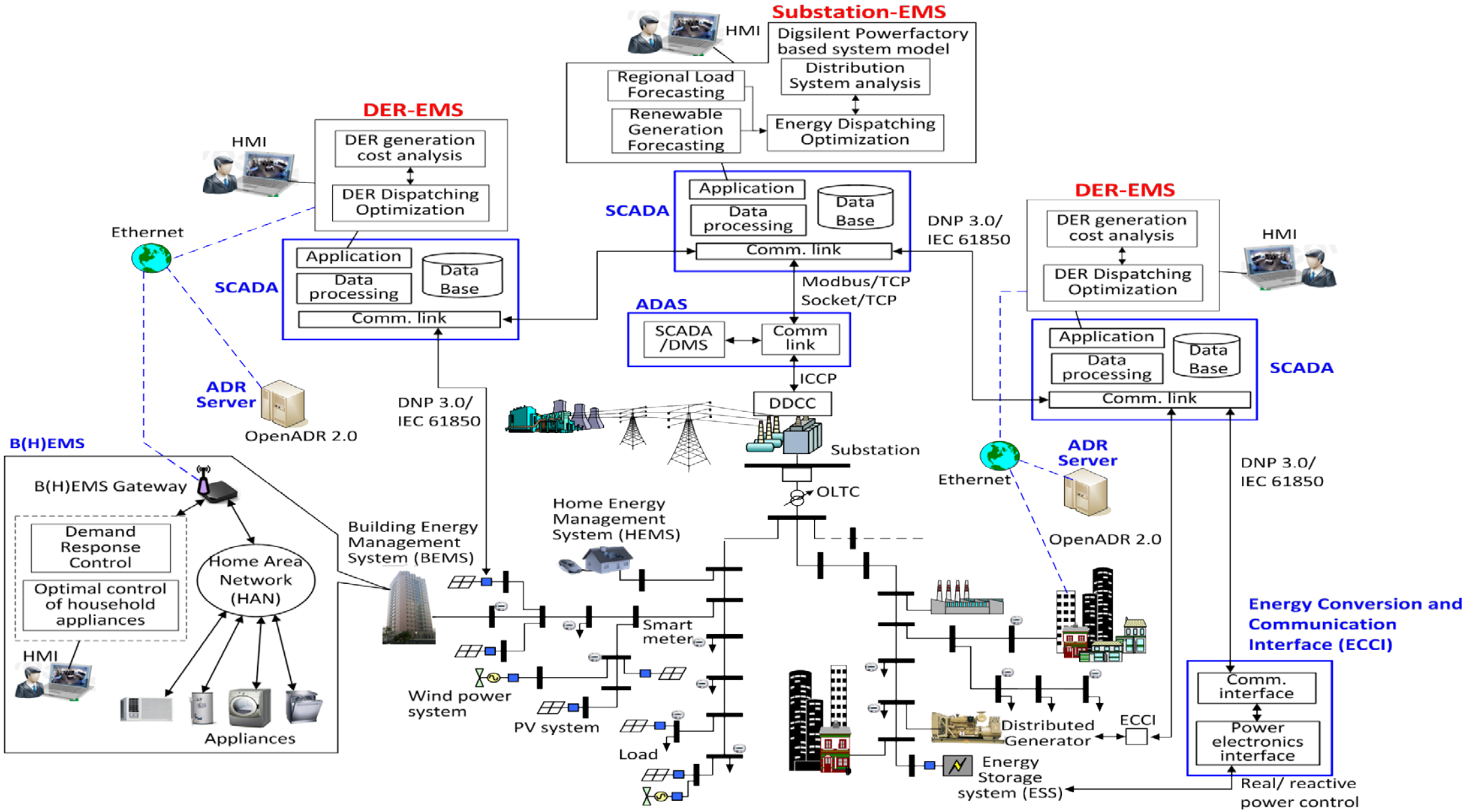
Wind-turbine



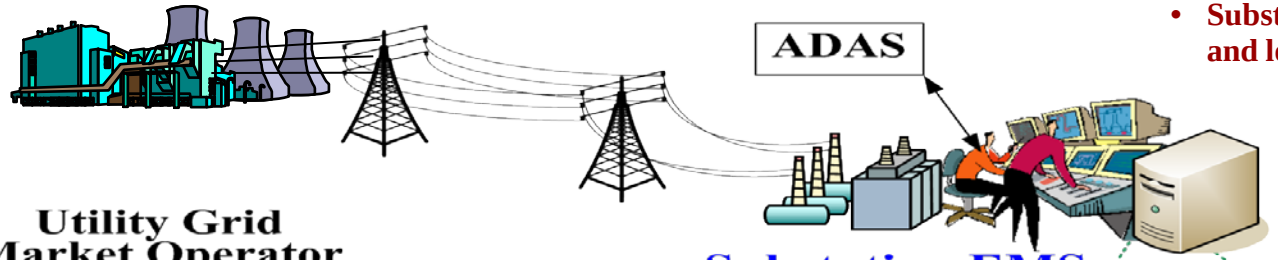

BEMS

Diesel-Engine Generator

# DER-EMS & Substation EMS Architecture



# Planning Framework of DER-EMS and Communication and Control Standards




- Substation EMS Power quality analysis and load transfer control
  - Failure Analysis / Load Transfer
  - System stability / Dynamic analysis
  - Active/reactive power compensation analysis

- Run the testing Taipower demonstration site ,(PV, Battery),, Taipower suggested congestion areas

Utility Grid
Market Operator

IEC 61850
DNP3

- DER-EMS operation station system

- DER-EMS energy management decision-making system

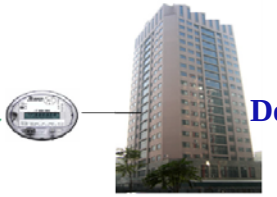
Generation cost analysis
Benefit optimization of participating market
Risk management of forecasting error

IEC 62056
IEC 61968

AMI Data Center

- Small area load forecasting

Customer



Demand response


Smart Home (Building) Energy Management System (SHMES)

IEC 62196
SAEJ1772

EV Charging

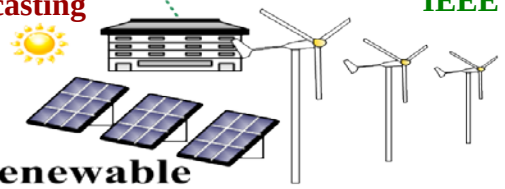
IEC 61850-7-420
IEEE P2030.2


Energy Storage System (ESS)

- Potential transformer active/reactive power control voltage/frequency regulation

IEC 61850-7-420
/IEC 61400-25

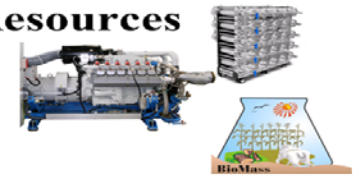
- Renewable energy generation forecasting



Renewable Generation System

IEC 61850-7-420
IEEE P2030.2

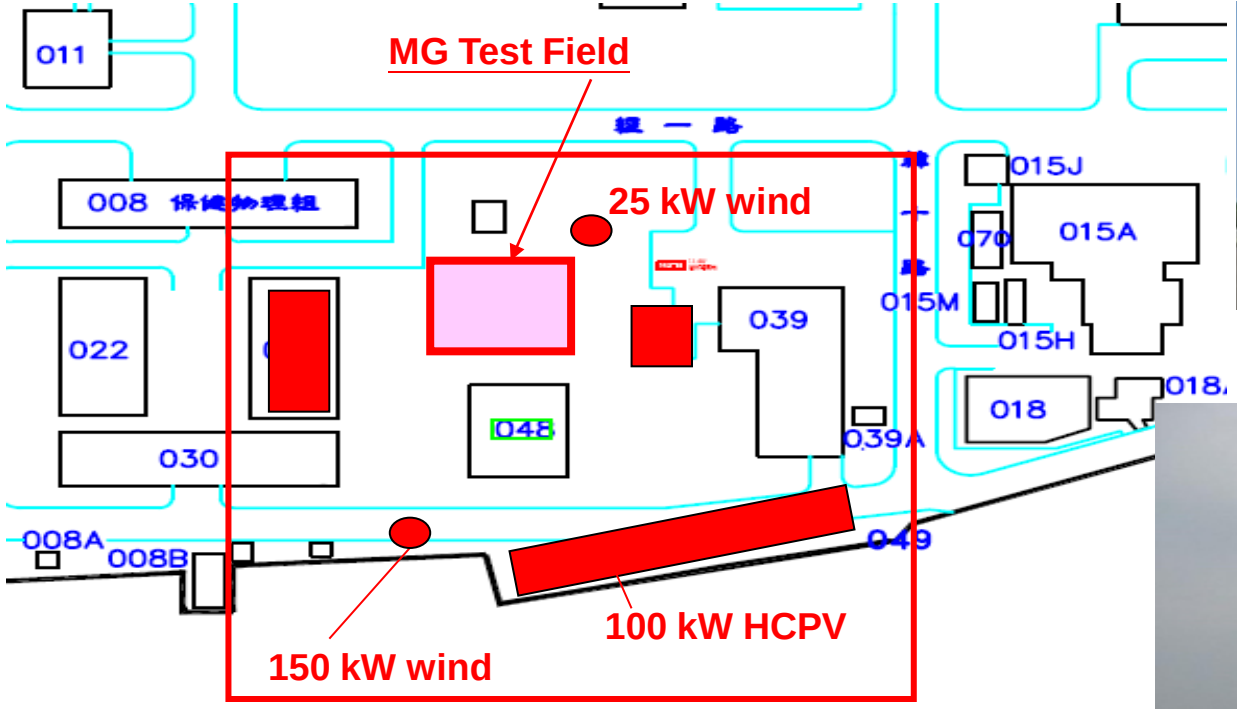
Distributed Energy Resources



CHP, Biomass, gas turbines, diesels, Fuel Cell, and Heat Pump

# NEP II - AC Microgrid Demonstration Project

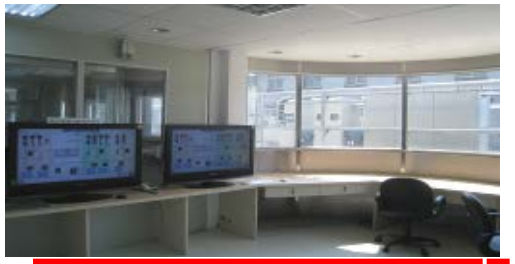
# AC Microgrid Demonstration Site




100 kW HCPV

150 kW wind


MG Test Field



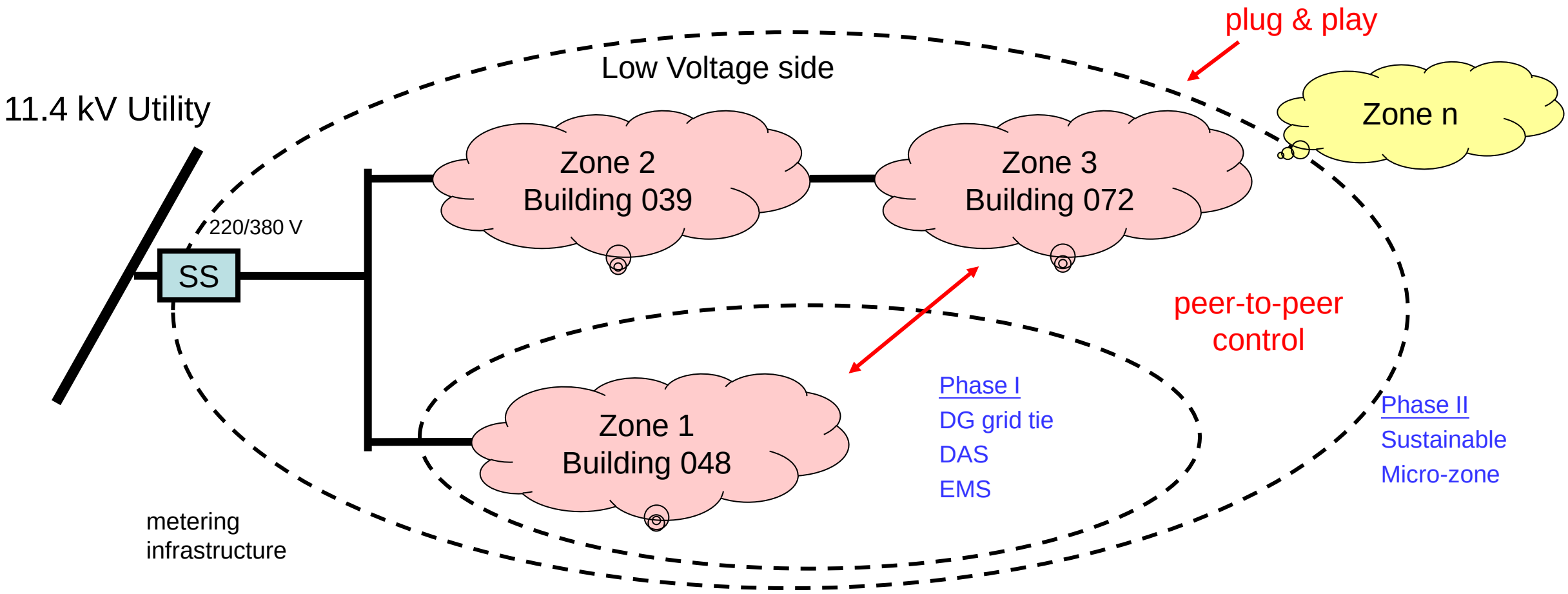
Control Room

250 kW ES

65 kW x3 MT

**Target:** Developing power control and management technology for low voltage side of microgrid with three zones in which 20% of total energy comes from renewable energy.

**Microgrid EMS** can be used to perform seamless transition control between grid connected and stand alone operation successfully.



# Microgrid Technology Development

## (1) Power System Technology

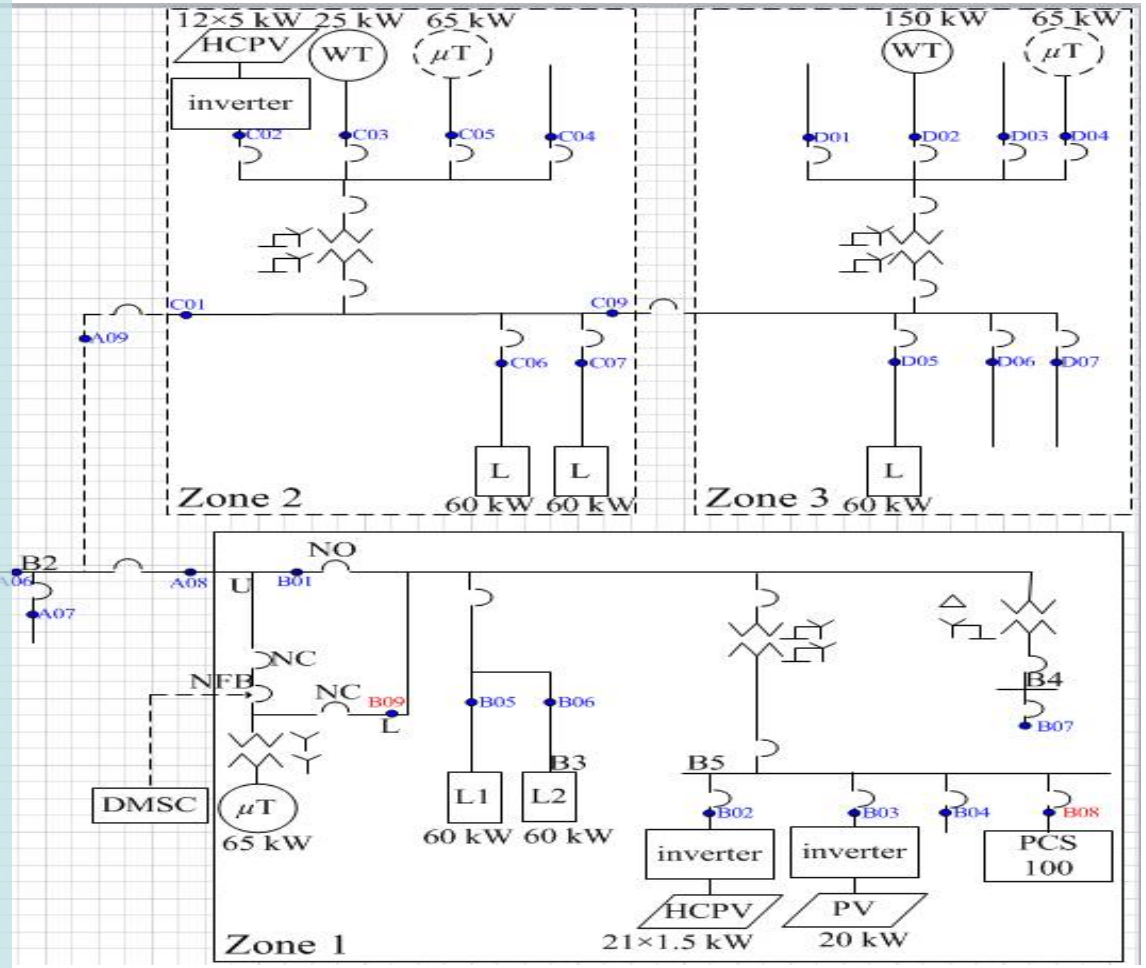
- Operation Scenarios Design & Testing
- System Stability Analysis
- Protection Coordination for MG
- Microgrid Power Quality Analysis

## (2) Power Electronics Technology

- Static Switch and Islanding Detection
- Smooth Switching Inverter
- Active/Reactive Power Control
- Droop Control
- Low Voltage Ride Through

## (3) Intelligent control and EMS

- Energy Management System
- Power Flow Analysis
- Generation & Load Prediction
- DAQ and Time Synchronization

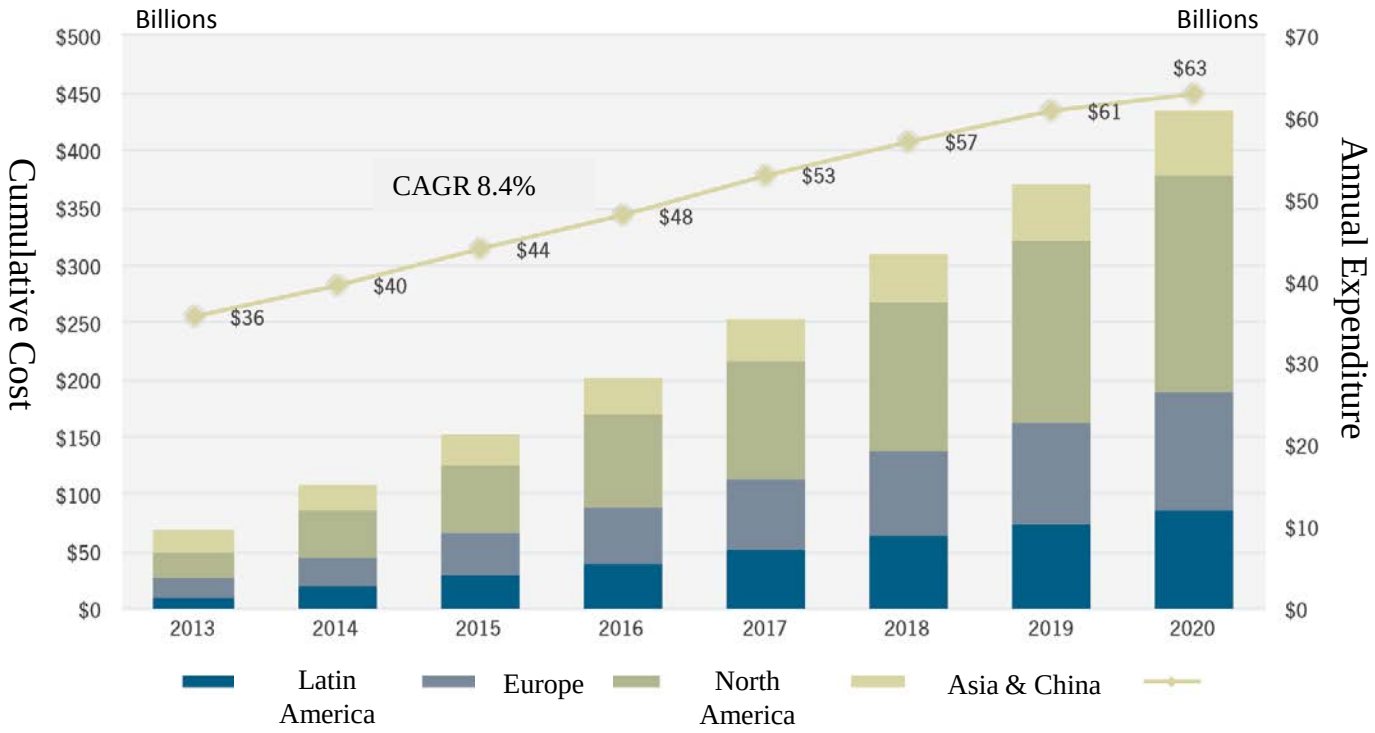


# Development of Smart Grid Industry in Taiwan

# Global Development of Smart Grid Market

The construction development of smart grid around the world has begun, and the output value of smart grid global market will continue to grow sustainably.

- **Whether grid update projects of developed countries or grid infrastructure installation of developing countries, all will continue over 20 years or more.**
- **According to the analysis done by international research institute GMT, the total output value of smart grid global market will generate over $400 billion with 8% of compound average growth rate (CAGR). It can be expected that the output value of smart grid global market will continue to grow sustainably in the future.**



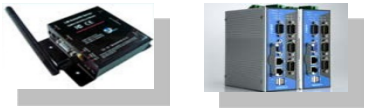

Source：2013 ~ 2020 over output value of smart grid (Source：GTM 2013)

# Vision of Smart Grid Industry in Taiwan

**With power, electrical electronics & IT industries' power combined, the output value of Smart-Grid Industry in Taiwan is estimated to reach NT$70 Billion in 2020, and NT$170 Billion in 2030.**

■ Traditional Power Equipment Industry：
Generator, Electric Motor, Micromotor, Transformer, HV&LV Panel, Circuit Breaker

■ Smart-Grid IT Equipment Industry：
MDMS, Communication Module, Sensors

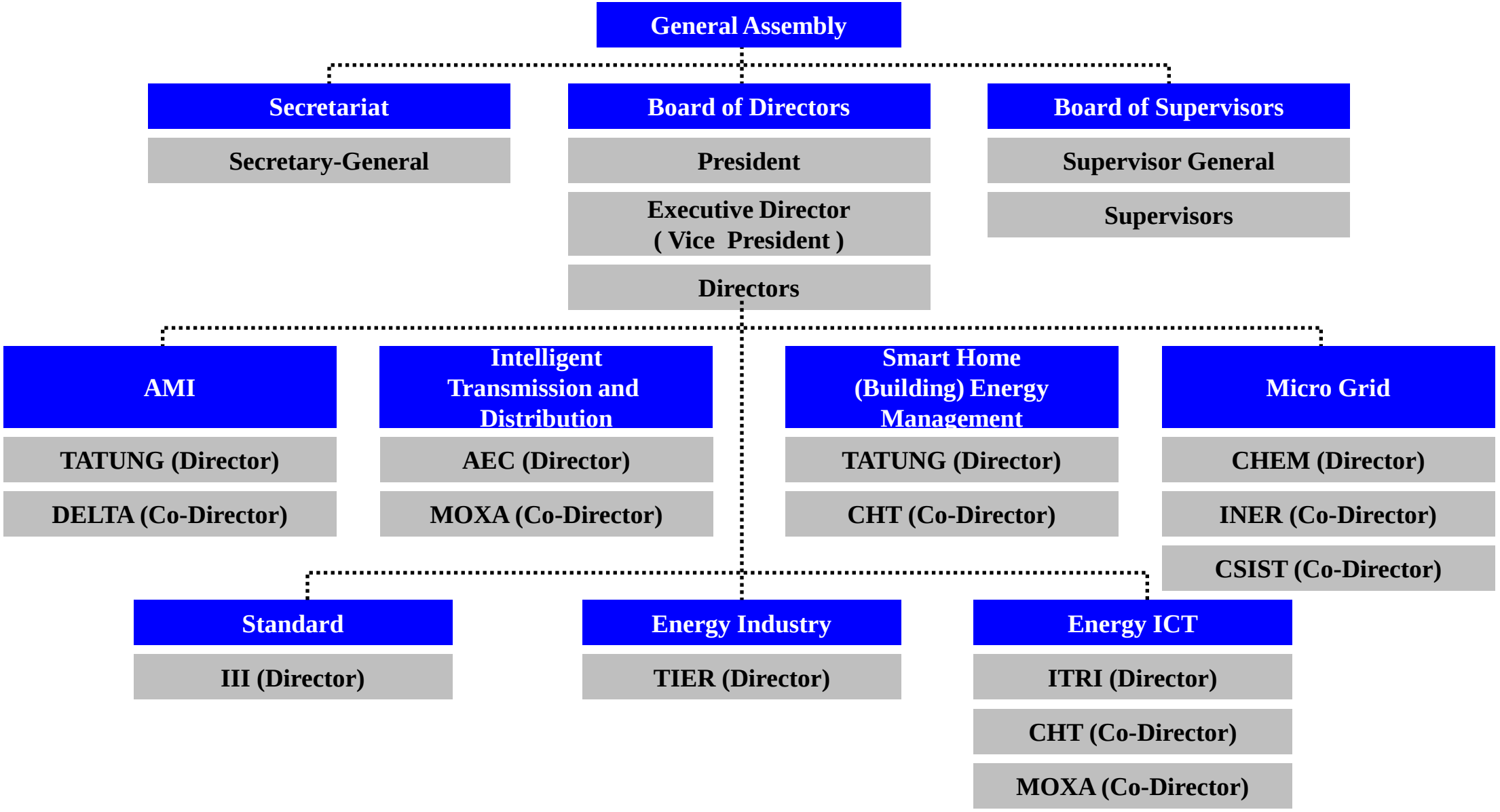






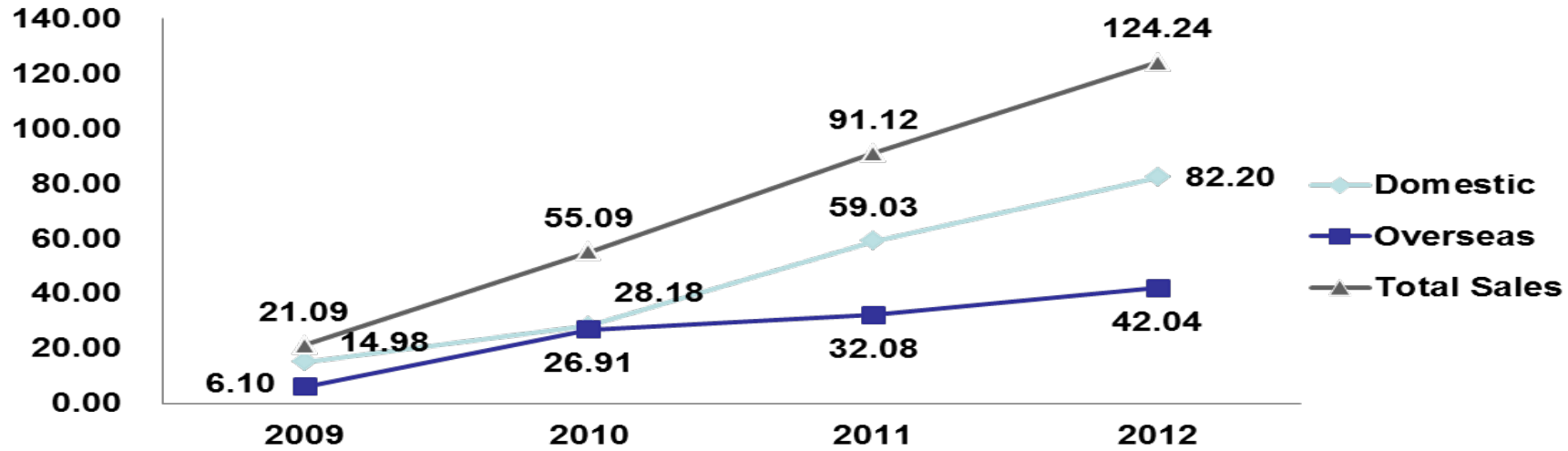

■ Smart-Grid Power Equipment Industry：
HV&LV Single-Phase Smart Meter System、Smart Substation、Feeder Automation、H(B)EMS

# Structure of TSGIA



# Results of Smart Grid Industry Survey in Taiwan

According to the surveys that were conducted in 2012 and 2013, the result shows that the total sales of Smart Grid related products continue to grow steadily and **have a Compound Annual Growth Rate (CAGR) of 80.62%. The market of Smart Grid in Taiwan is growing at a steady rate,** but because of the development of the global economy did not turn out as expected and caused negative impact on the oversea markets, the oversea sales has decreased in 2011. However, the overall performance of the industry remains positive and still growing.




| | Domestic | Overseas | Total Sales | Domestic | Overseas | Growth Rate | CAGR |
|---|---|---|---|---|---|---|---|
| **2009** | 14.98 | 6.10 | 21.09 | 71.07% | 28.93% | - | 80.62% |
| **2010** | 28.18 | 26.91 | 55.09 | 51.15% | 48.85% | 161.25% | |
| **2011** | 75.83 | 15.28 | 91.12 | 64.79% | 35.21% | 65.41% | |
| **2012** | 100.44 | 23.80 | 124.24 | 66.16% | 33.84% | 36.36% | |

Unit：NTD in 100 million dollars

# Challenges of Smart Grid Development in Taiwan

1. Due to low SAIDI and transmission loss, the power system in Taiwan is still robust. The development of smart grid in Taiwan should be focused on the massive deployment of renewable energy resources to avoid the shortage of power resources the massive deployment of low voltage smart meters for the implementation of demand response and real-time pricing.
2. The installation target of renewable energy resources of Taiwan in 2030 is 13.75GW including PV 6.2GW , onshore WTG 1.2GW and offshore WTG 3GW. Is it enough to compensate the shortage of power generation due to the decommission of all the nuclear power plant in 2015？ (Predicted maximum installation capacity of renewable energy resources is 24.5GW.)
3. Finally, we have an electricity price equation (since April, 2015). Will it be effective?

$$\frac{\text{A(Fuel Cost)} + \text{B(Other Costs)} + \text{C(5\%Profit)}}{\text{D (Sales kWh)}} = \text{P(Electricity Price /kWh)}$$

Can the cost to improve the transmission and distribution system to accommodate massive renewable energy resources be put into the electricity price equation? Can the cost of massive deployment of low voltage smart meters be put in the electricity price equation?

4. Currently, government has concern for the increase in electricity price would trigger inflation; therefore, electricity price is strictly controlled. So, who is going to pay? It is unfair to ask Taipower to pay.
5. Strongly suggest that every reasonable cost to improve the grid should be considered in the electricity price equation. However, "Use more pay more!" is a cliché which is difficult to achieve in Taiwan.
6. Taipower has already lost more than half of its capital (7 billions USD) and is now facing the financial crisis of the suspended construction of no. 4 nuclear power plant (10 billions USD). Owing to financial difficulty, Taipower is certainly very reluctant to face the above issues.

7. Taipower still does not have enough confidence in smart grid technology; therefore, when facing challenges related to power system, they often use traditional thinking such as adding more concentrated generation sources and transmission infrastructures.
8. Smart grid demonstration project is very conservative when it comes to site selection; therefore, the overall scale of the demonstration site does not reach the minimum threshold, and as a result, the new technologies are unable to demonstrate effectively.
9. Because of the slow progress of electricity market liberation, smart grid does not have corresponding business model when entering the market, which hinders the wellness of the market development.
10. The bottleneck areas of electricity are mainly traditional city areas; old buildings and city structure limit the implementation of new technology and the expansion of user participation.

# Thank You for Your Listening!