Overview of Microgrid Research in Taiwan

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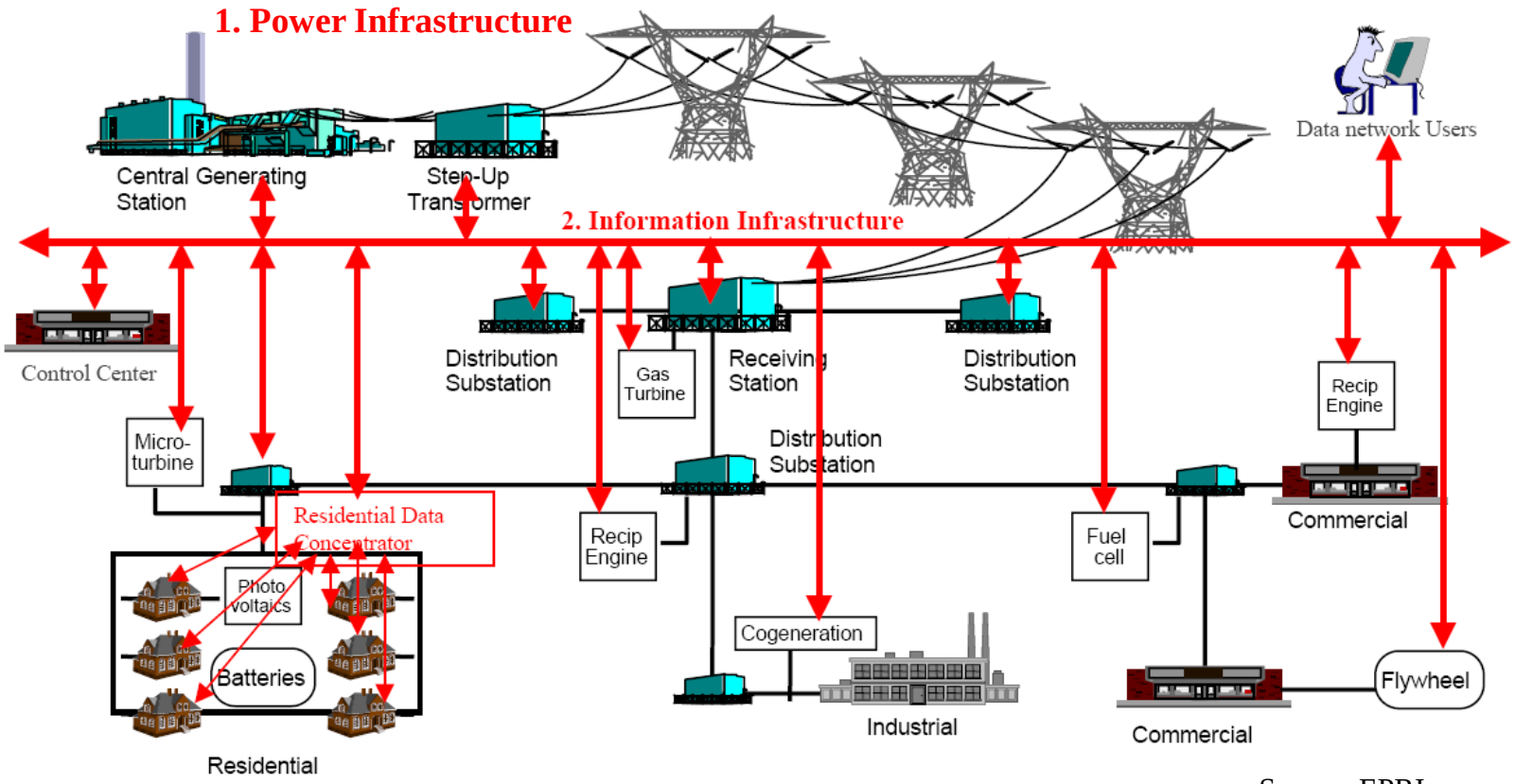
Outline

- **What is smart grid**
- **Taipower's vision on smart grid**
- **Strategic initiatives of smart grid in Taiwan**
- **Overview of microgrid research in Taiwan**

What Is Smart Grid?

Integrate electric power and information/communication technologies to enable better energy management from generation, transmission, distribution to user.



Source: EPRI

Advantages of Smart Grid

- Improve the overall efficiency for user (by ICT, AMI)
- Improve the proportion of distributed power or renewable energy to total generating capacity (by microgrid and distribution automation)
- Increase the flexibility of supply (by distribution automation)
- Reduce the transmission and distribution losses
- Improve power system stability and power quality (by self-healing)
- Reduce the peak load to reduce the spinning reserves (by AMI, demand response and time of use)
- Improve energy security
- Promote the development of information and communication industry

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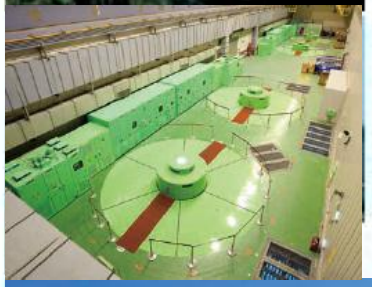
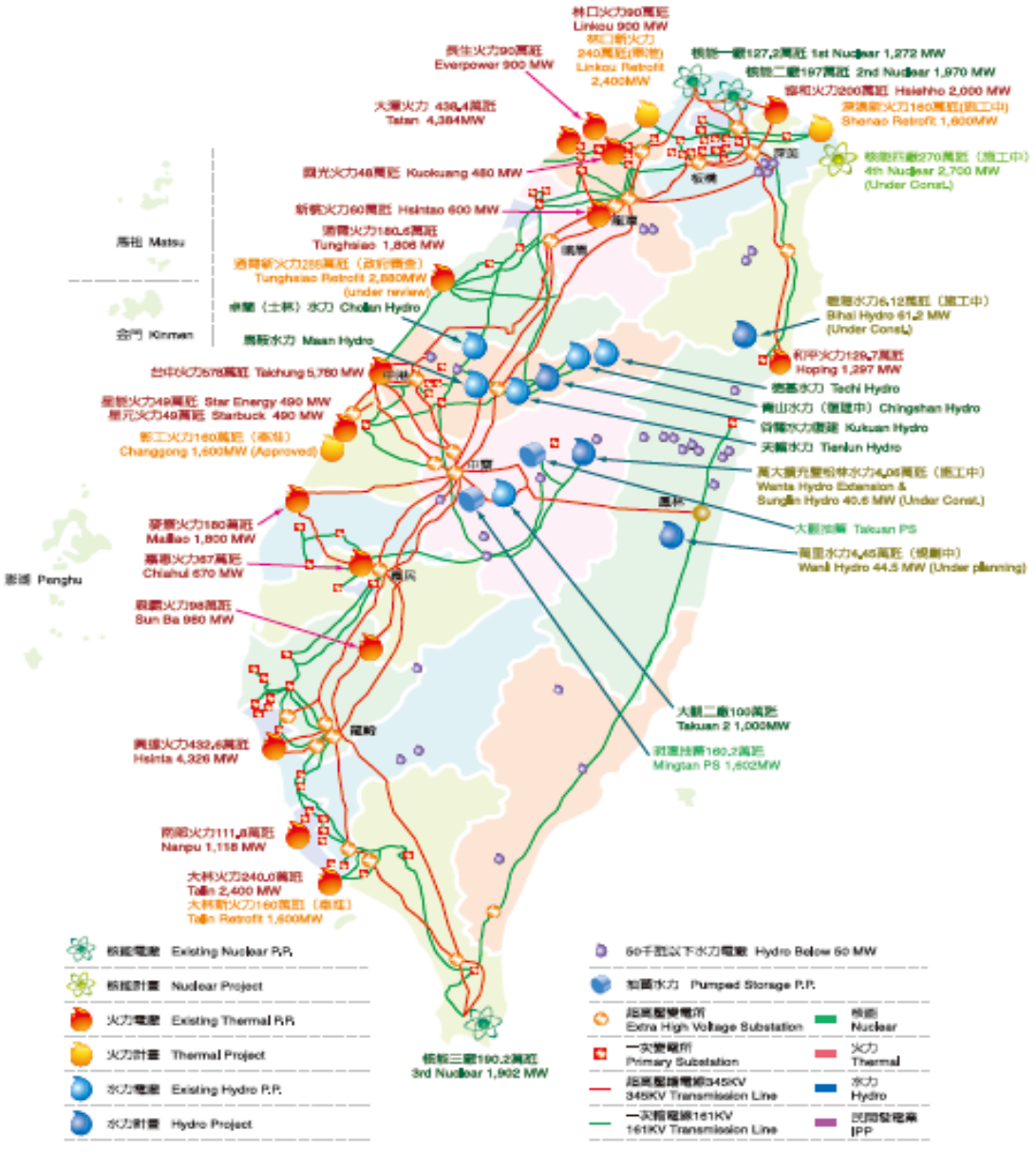
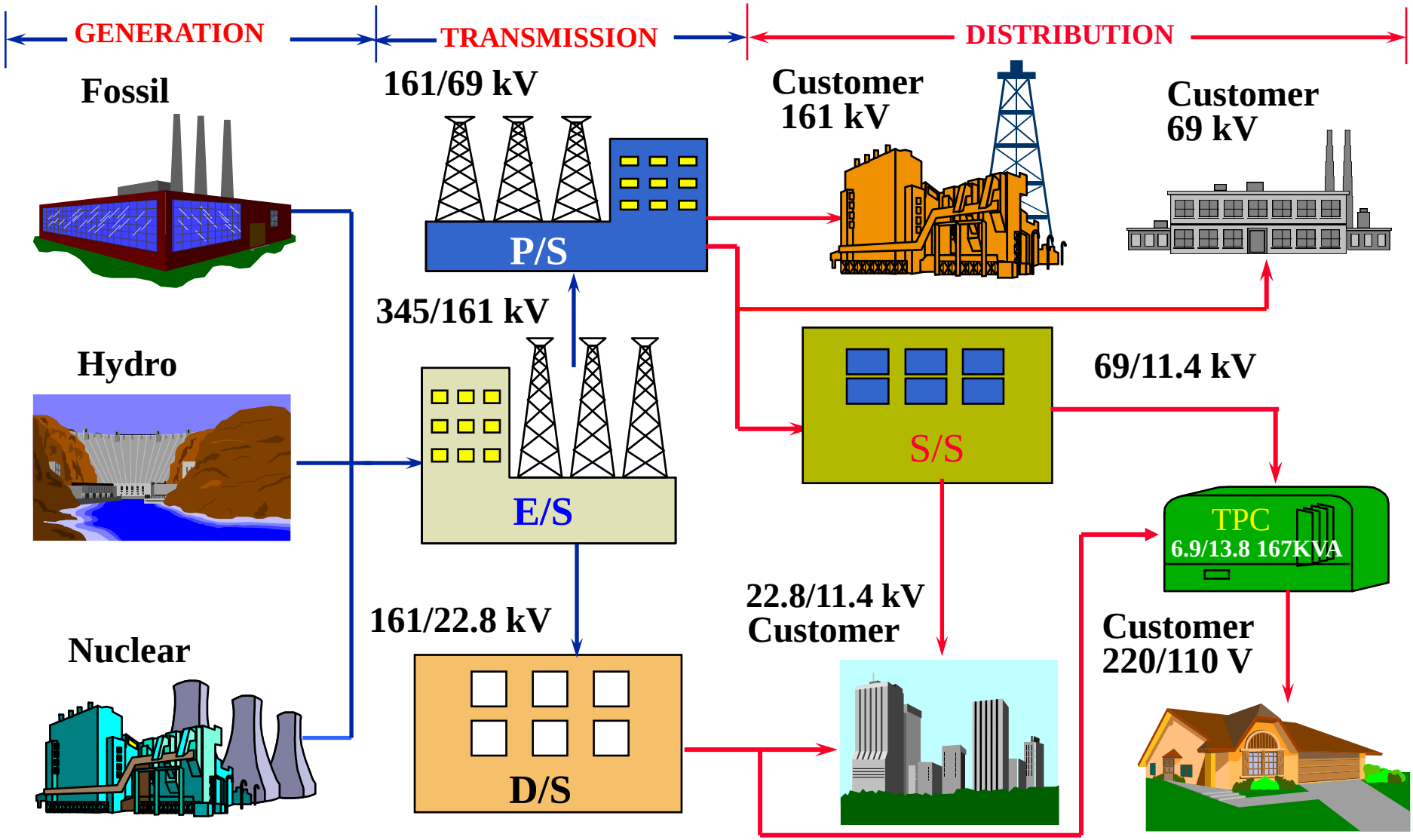
Overview of Taipower's System

- Installed capacity ≒40.25GW
- Hydro (pump) 2,600 MW
- Thermal 30,194 MW
- Nuclear 5,144 MW
- Renewable 2,306 MW





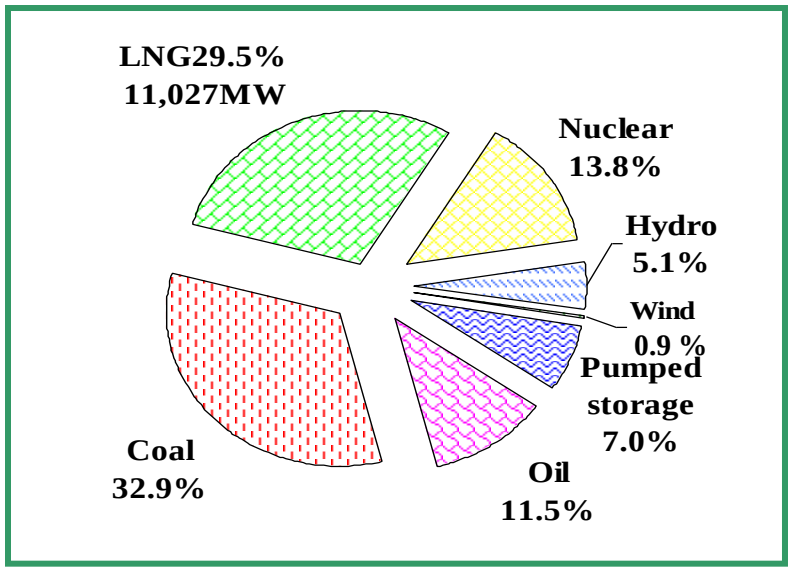
Overview of Taipower's System



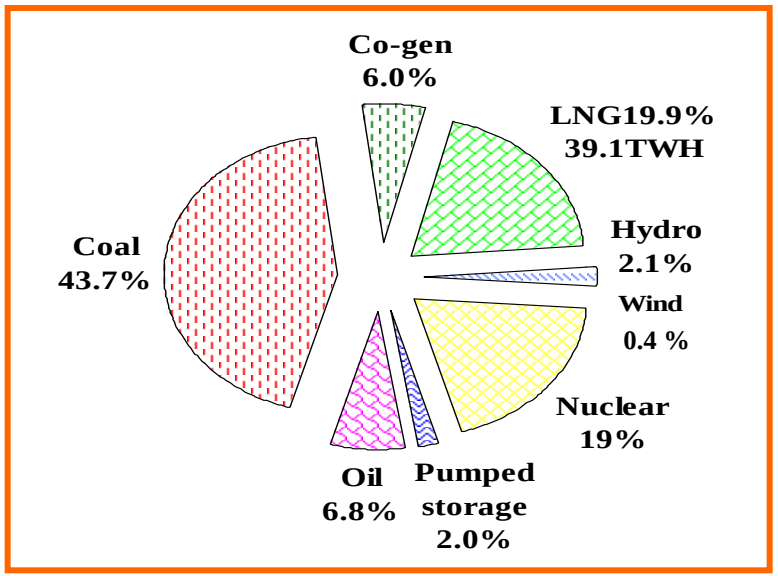
Overview of Taipower's System

Up to year 2009

- System Installed Capacity: 40,247 MW
- Peak Load: 31,011 MW
- Total Generated Electricity (+IPP): 193.6 billion KWh
- Sale Electricity: 179.2 billion KWh
- Customers: 12,414,679
- Line loss: 4.86%



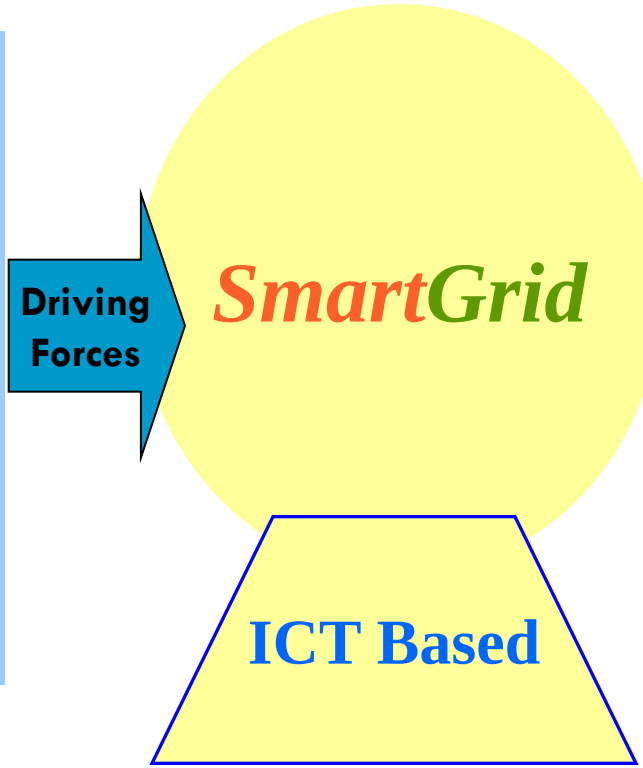
Installed Capacity (40,247 MW)



Generation (193.6TWh)

Taipower's Vision on Smart Grid (*cont.*)

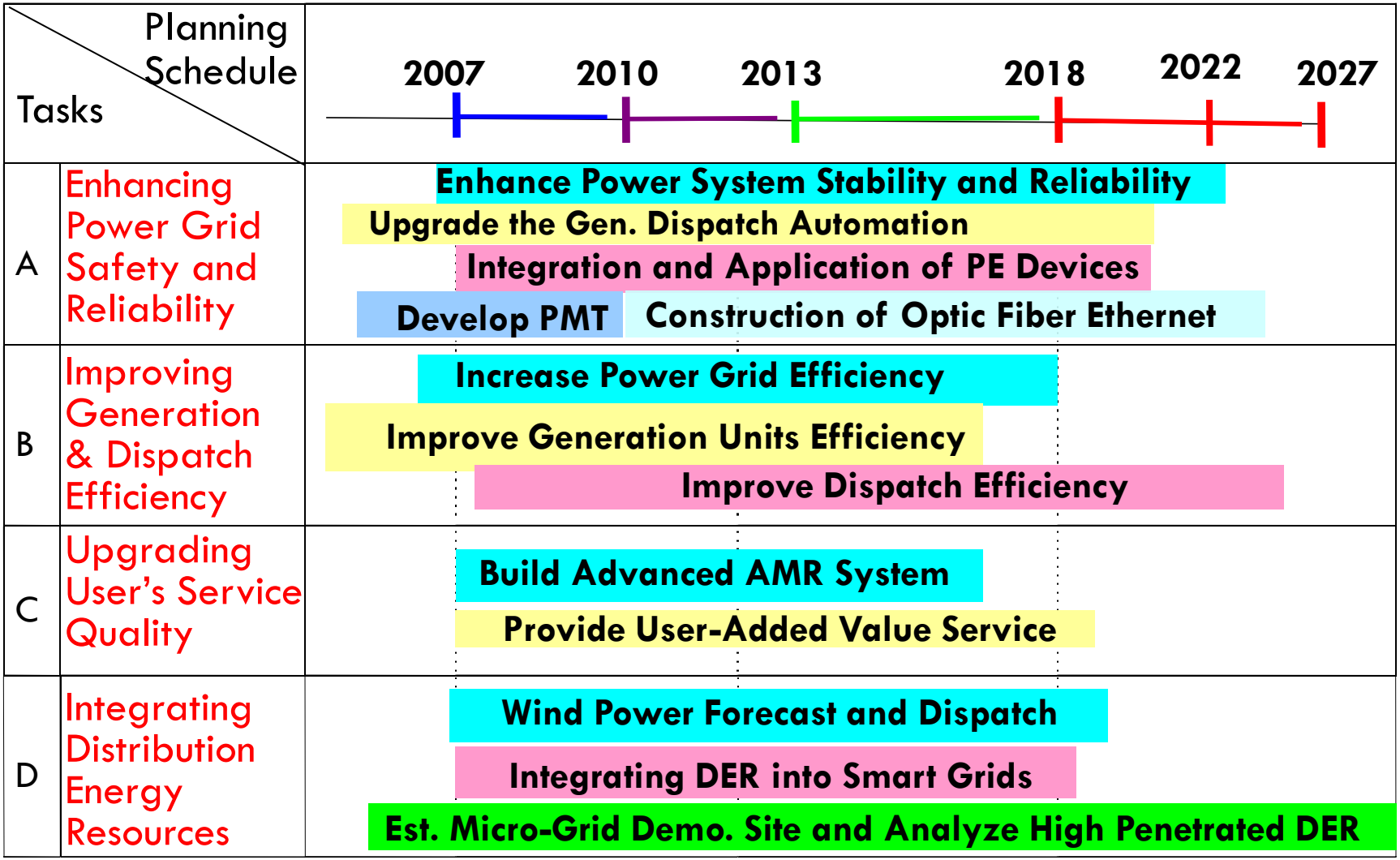
- **Reliable Power Supply with High Power Quality**
- **Productivity Improvement**
- **Carbon Footprint**
- **Communication, Information and Power Electronics Technology Improvement**



Create a high-quality, high-efficiency, customer service-oriented, and environment-friendly power grid.

- **A higher safety and reliability of power network**
- **Higher efficiency of power plants**
- **Service-oriented system**
- **Environment-friendly grid**

Taipower's Vision on Smart Grid - Roadmap



PE: Power Electronics PMT: Preventive Maintenance Technology

Supporting platforms: Communication Protocol Guideline and Knowledge Base

Smart Grid for Transmission System

- Asset Management: **Main Transformer Asset Management constructed in 2008; the risk assessment of power supply stability and safety finished in 2009.**
- Automated Asset Condition Assessment: **RFIDs are applied for equipment, remote reading and analysis software developed in 2009.**
- Automated Fault Location: **Software has been developed in 2009**
- SVR: **Feasibility study: 2006, Construction Plan: 2011-2015**
- SVC: **Feasibility study: 2008, Construction Plan: 2012/2013 (in East Taiwan)**
- STATCOM： **Construction Plan: 2013 (LungTan, 150MVA)**
- Enable Wide Area Monitoring & Control: **PMUs have been installed in 2005, and several advanced features are under development.**
- Integrate Demand Responsive Resources: **The first stage program was operated in 2008, and will be promoted with sufficient incentives.**

Distribution Feeder Automation

- Finished 53% of feeders with FDIR (Fault Detection, Isolation and Service Restoration)
- function in year 2012
- Increase the number from 2,110 to 6,256 feeders
- Main stream is the open loop type

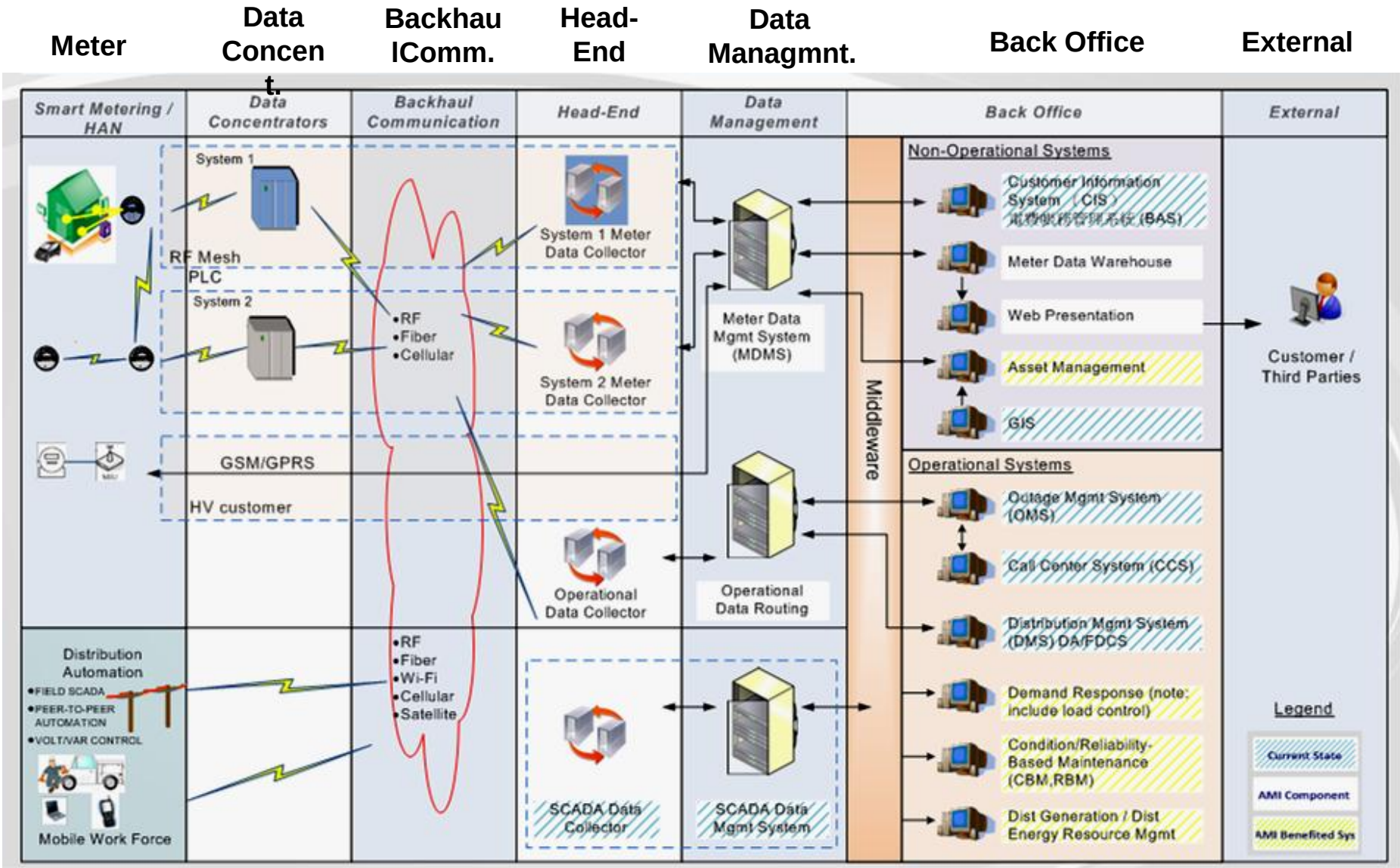
High-Voltage AMI Timeline

High voltage AMI total 23300 meters covering 59% electrical power consumption of Taipower will be installed before 2012.

Low-Voltage AMI Timeline

	1'st Stage (Tech. test)		2'nd Stage (Preliminary Installation)		3'rd Stage (Fundamental Installation)			4'th Stage (Extended Installation)
Year	2009	2010	2011	2012	2013	2014	2015	2016 ->
Meter No.	50	300~500	10,000	Technology Confirmation	1,000,000	Cost/Benefit Assessment		5,000,000
Working Items	Communication Technology Testing	*Define Function and Standard *Test Platform Plan	*MDMS Meter Function Test *Meter Function Std. ID. *Construct Test Platform *Construct New TOU Fee		*Meter Installation *New TOU Fee Execution *Load Management and Demand Response Study			*Construct Distribution Automation System *Apply Load Management and Demand Response

Overall AMI Architecture



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Strategic Initiatives of Smart Grid in Taiwan

Vision

Develop the smart grid and AMI industry in Taiwan to establish high quality, high efficiency, user-oriented and environment-friendly power system to reduce CO_2 emission, increase energy efficiency and enhance energy security.

Strategy

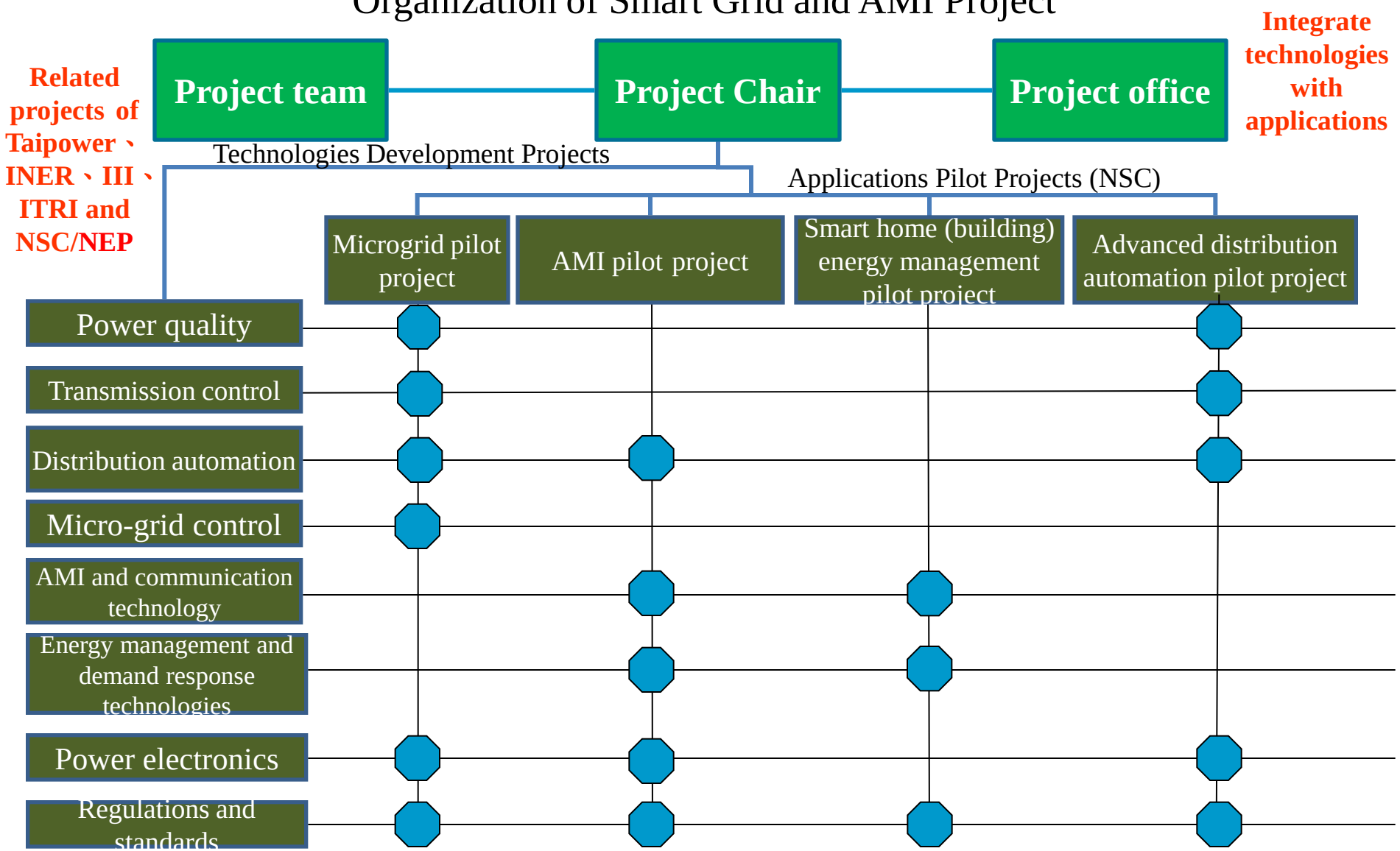
Tying in closely with the smart grid developing schedule of Taiwan Power Company, integrate the research abilities of industry and academia to establish smart grid and support the power facilities industry in Taiwan.

Manner

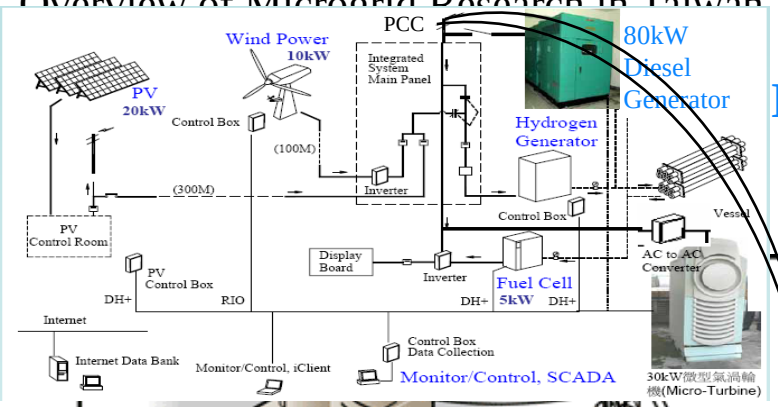
Promote AMI, microgrid, smart home (building) energy management system, advanced distribution automation four pilot projects by National Science Council (NSC) to develop key technologies of smart grid and AMI and ensure the merging of the developed technologies into the power system in Taiwan will be reliable and feasible.

Strategic Initiatives of Smart Grid in Taiwan (*cont.*)

Organization of Smart Grid and AMI Project



Strategic Initiatives of Smart Grid in Taiwan (*cont.*)

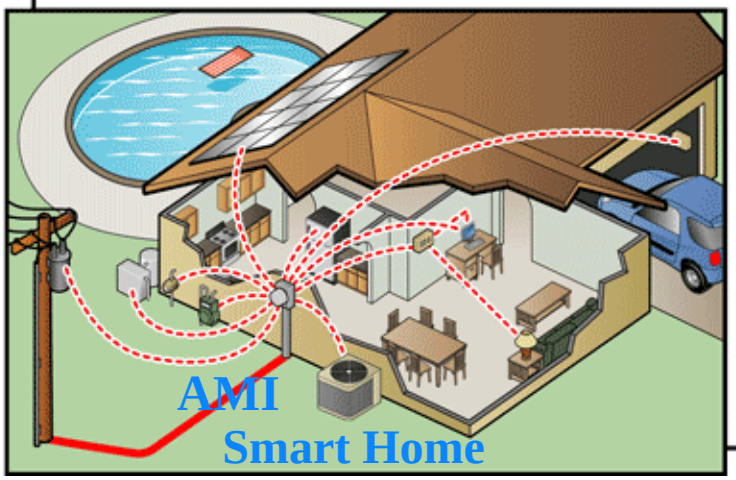


Microgrid System

ADAS

In Data Center:
Billing/Customer service
Distribution automation
Energy management
Outage management

Data Center

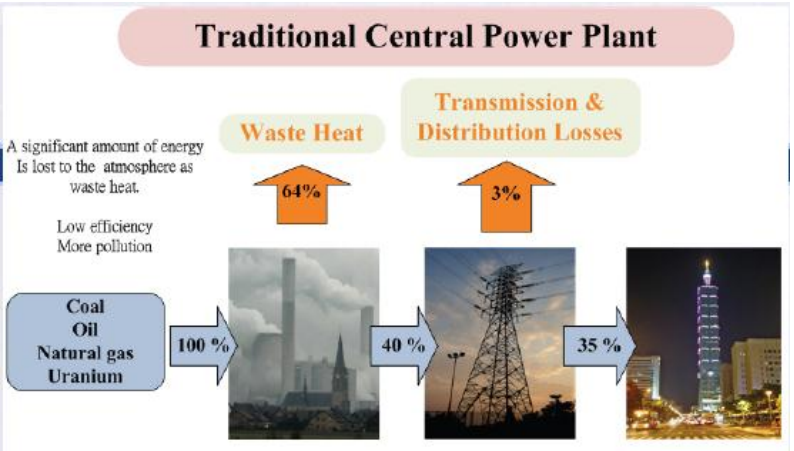


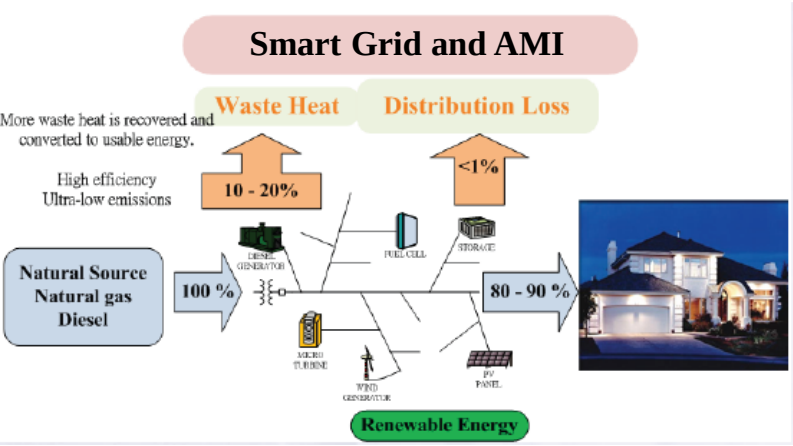
AMI
Smart Home

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

Southern California Edison

The Past and The Future of Power System





The past
- Centralized power plant
- Low proportion of DG
- Few islanding operation
- From generation, transmission, distribution to user: overall energy efficiency 30~40%

Smart Grid and AMI Technologies Development
- Power quality
- Transmission control
- Distribution automation
- Micro-grid control
- AMI and communication technology
- Energy management and demand response technology
- Power electronics
- Regulations and standards

Smart Grid and AMI Pilot Projects
- Microgrid pilot projects
- AMI pilot project
- Smart home (building) energy management pilot project
- Advanced distribution automation system (ADAS) pilot project

The future
- High proportion of DG (including renewable energy)
- Using microgrid and ADAS technologies, distributed network can be connected to the grid or operated in islanding
- Using AMI with demand response (DR), time of usage (TOU) strategies, saving and generating electricity become a concern of public
- Significant improvement of overall efficiency due to regional power sources supply local loads

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Microgrid Pilot Project in INER

Recent

In order to increase usage of renewable energy and to ensure safety operation of electric utility system, the objectives of this project is to develop power control and management technologies for a microgrid, which include

(1) power conversion system with reactive power control for renewable energy,

(2) energy storage system,

(3) grid tie static switch with seamless transfer to stand alone operation,

(4) protection and coordination of a microgrid,

(5) micorgrid system analysis and power quality analysis,

(6) backup power control and load shedding scheme for stand alone operation of microgrid.

Midterm and Long term

To construct Microgrid Test Field of Institute of Nuclear Energy Research (INER) and demonstrate autonomous control technique with penetration rate of renewable energy resources by 20%.

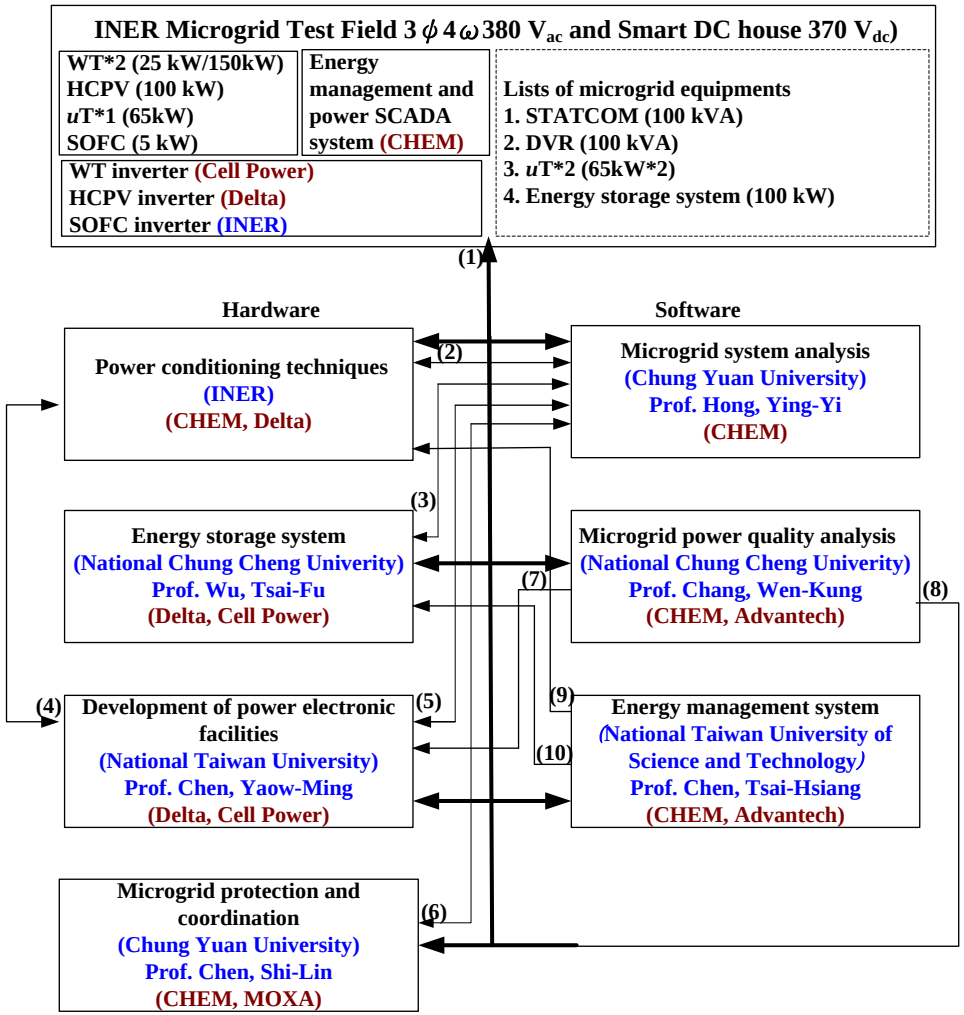
Project Planning

Microgrid Pilot Project

- Integration and coordination of subprojects
- Implementation of system engineering for a microgrid
- Development and transfer of microgrid technologies
- Promotion of domestic industries and international conferences

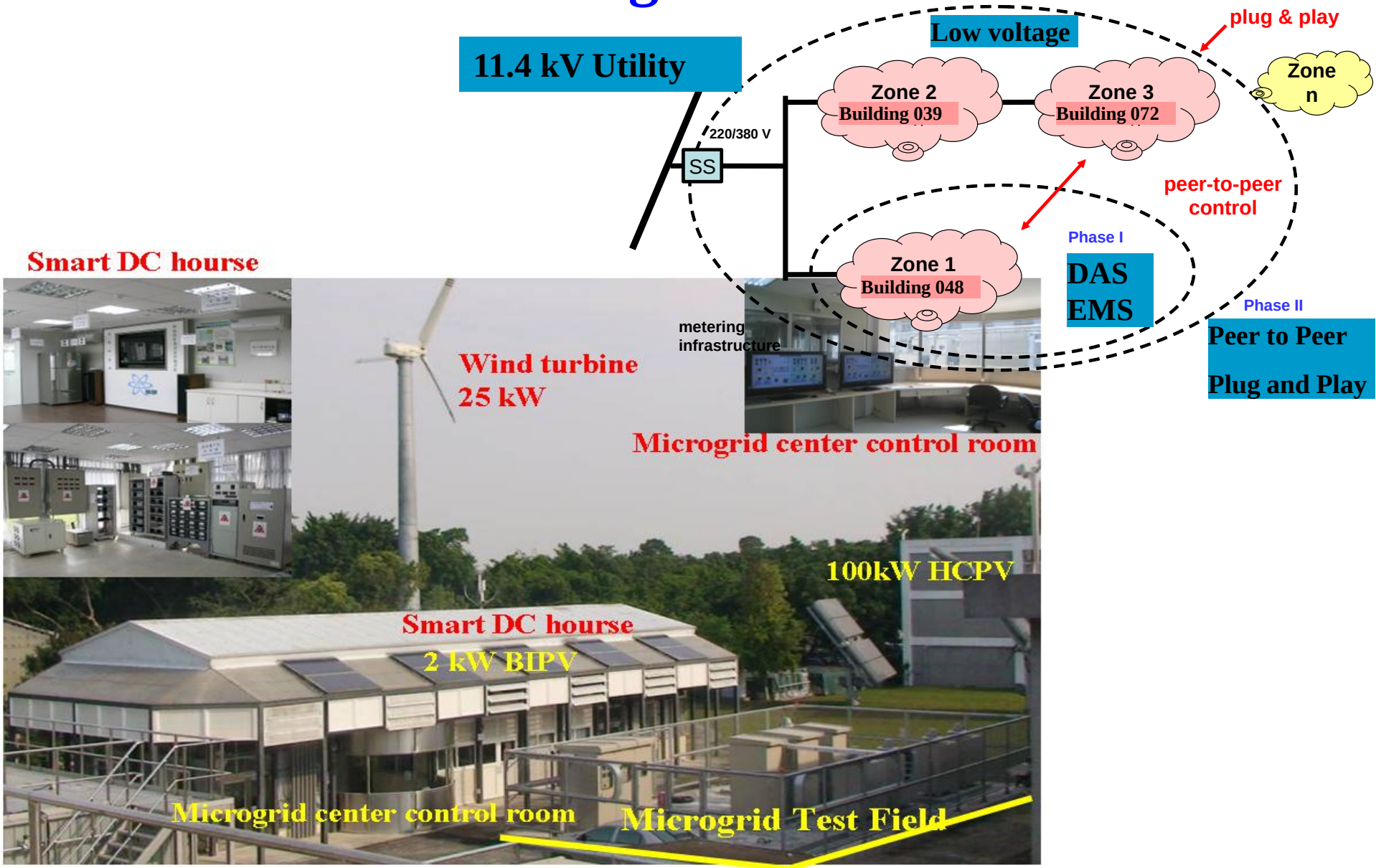
Subproject 1 **Power conditioning technique for renewable energy**	Real and reactive power control of inverter based DG Advanced detective and protective techniques for islanding
Subproject 2 **Energy storage system**	Bidirectional power control of energy storage system Current and voltage control of energy storage system
Subproject 3 **Development of power electronic facilities**	Static switch, DVR, and STATCOM Low voltage ride through technology
Subproject 4 **Microgrid protection and coordination**	Separation strategy of microgrid and corresponding protective relaying
Subproject 5 **Microgrid system analysis**	Transient stability analysis and load shedding scheme
Subproject 6 **Microgrid power quality analysis**	Analysis and improvement of unbalanced power flows Harmonics measurement, analysis, and mitigation
Subproject 7 **Energy management and control system**	Construction of full scale model of microgrid test bed Energy management system and intelligent control of microgrid

Integration of Subprojects



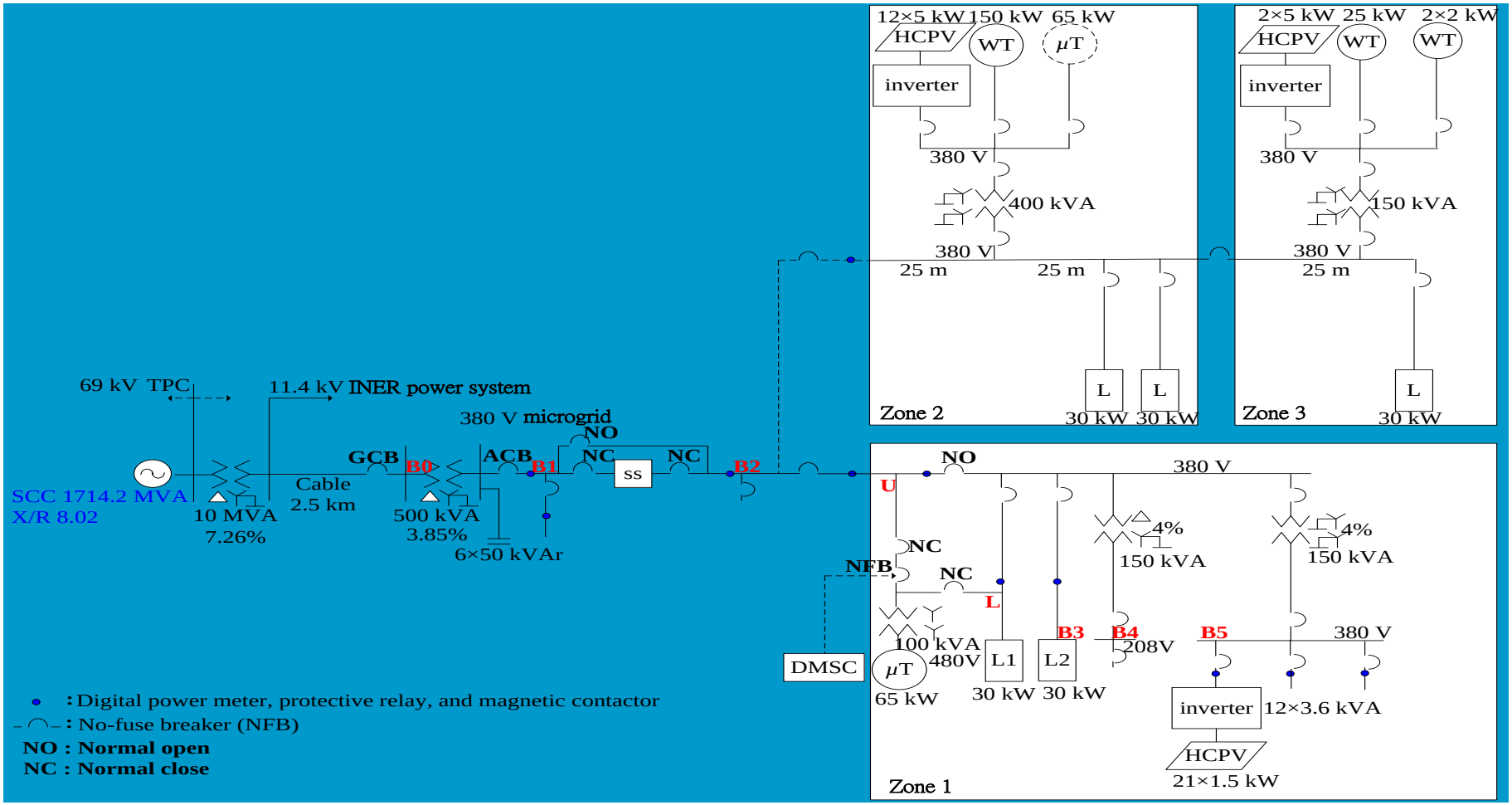
(1) System engineering of INER micorgrid
(2) Operation strategy of power conditioning systems and their protection function
(3) Operation strategy of energy storage system
(4) Voltage regulation equipped with LVRT technique
(5) Settings for the noperation of static switch
(6) Protective relay settings and load shedding scheme
(7) Settings of control parameters for voltage regulation equipments
(8) Power quality standard for microgrid
(9) power output of renewable generation
(10)Power output of energy storage system

INER Mircogrid Test Field



INER Mircogrid Test Field

System Configuration of INER Microgrid



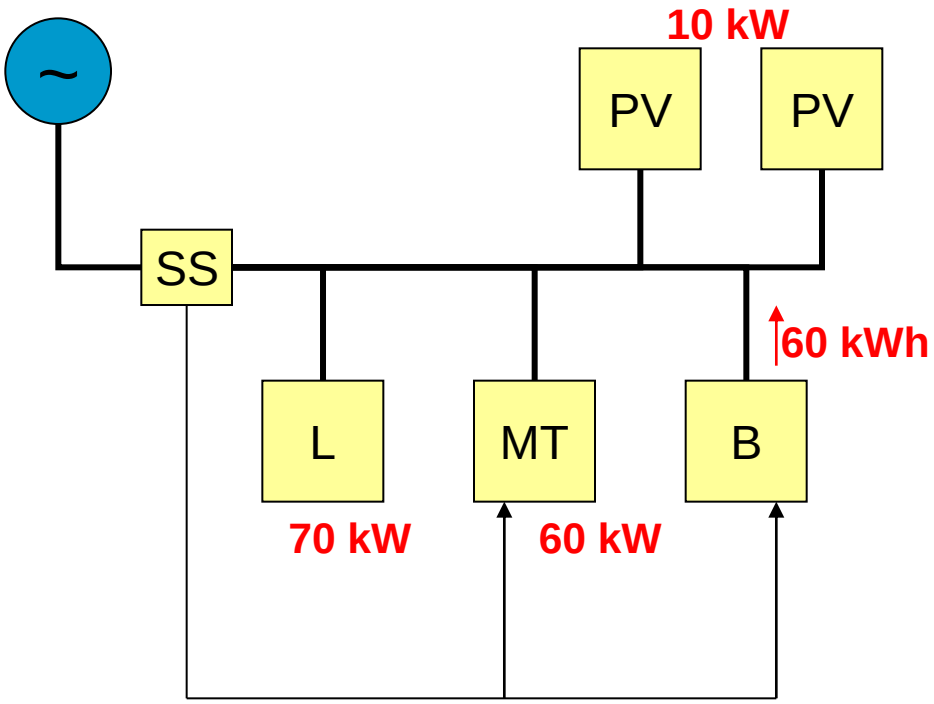
Implementation of System Engineering

Objectives (Condition : MT < L)

1. Stand alone operation
2. Penetration %

Step: (Initial :MT-off L,B,PV-on)

1. SS open
2. Check L、B & PV
3. MT on constant power
4. PV on-off-on
5. L 70 kW-60 kW-70 kW
6. SS close

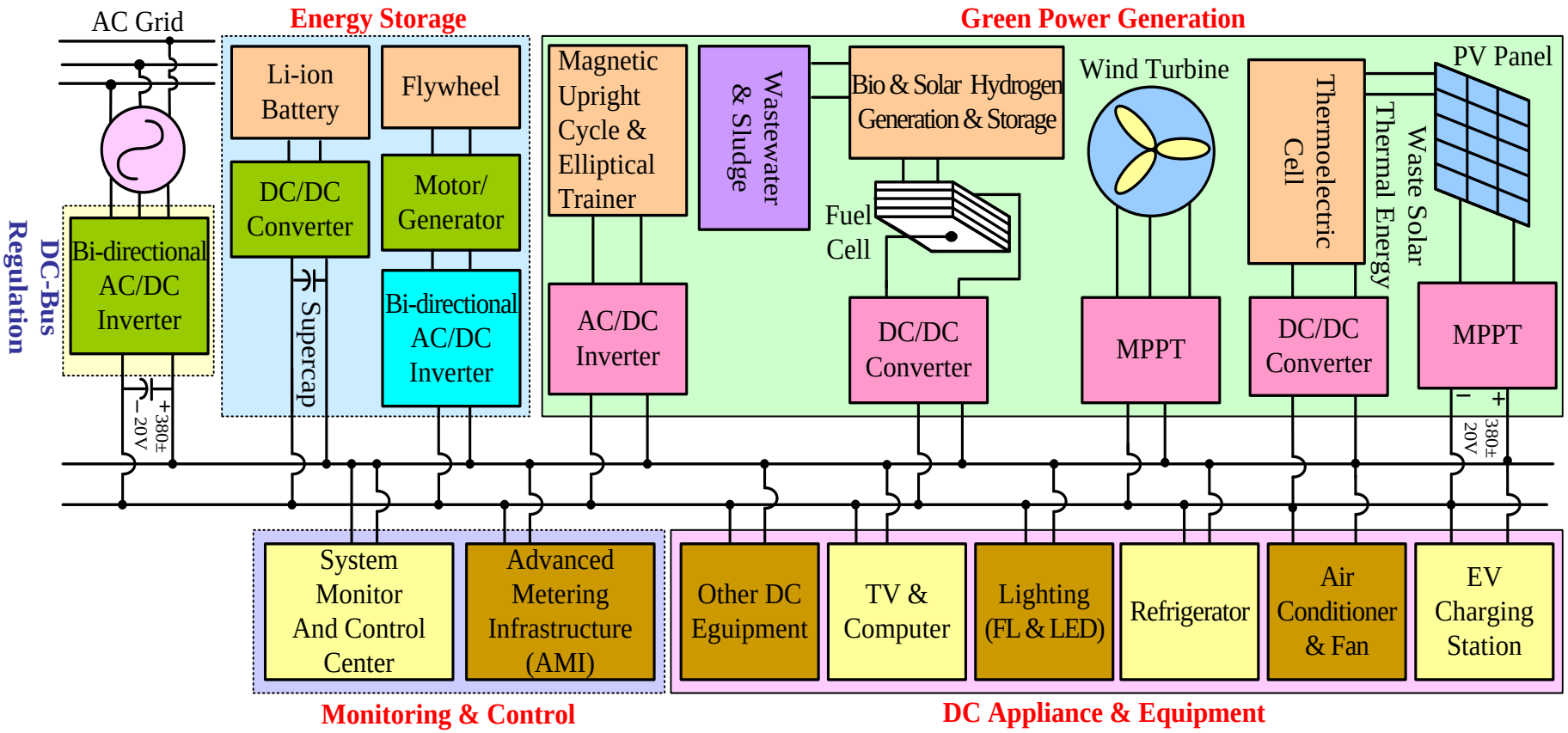


DC Microgrid Pilot Project in NCCU

Smart DC Microgrid

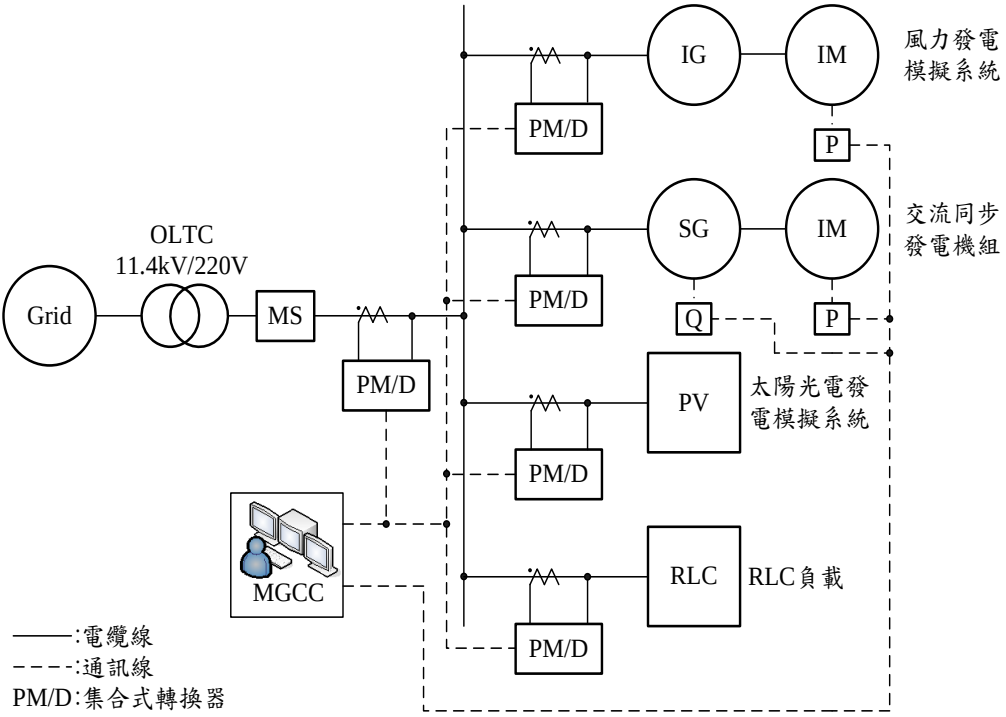
Team Project	Prof. Tsai-Fu Wu Title: Research on Smart DC Microgrid	1. Project coordination and cooperation 2. System implementation and installation 3. International technique exchange and conference activities 4. Domestic industry development and promotion
Division Project I Distributed Generation Systems	Sub-project I – Prof. Tsai-Fu Wu Title: Development of AC/DC Bidirectional Inverters	1. Design and implementation of AC/DC bidirectional inverters 2. Establishment of buy/sell power and dc-link voltage control mechanism 3. Establishment of dc-microgrid regulation
	Sub-project 2 – Prof. Yu-Kai Chen Title: Development of Multi-string MPPTs	1. Design and implementation of multi-string MPPTs 2. Establishment of multi-MPPT control strategy
	Sub-project 3 – Prof. Yu-Kang Lo Title: Research on Power Conditioner Control Technique for Fuel Cell	1. Design and implementation of power conditioners for fuel cells 2. Establishment of spare power control scheme
	Sub-project 4 – Prof. Sy-Ruen Huang Title: Impact on AC/DC grid Research	1. Investigation of dc-microgrid impact on ac grid during buy/sell power 2. Proposing solution for the described problems
	Sub-project 5 – Prof. Gwo-Ruey Yu Title: Dynamic Analysis of Microgrid Modules and DC Link Voltage Control	1. Establishment of microgrid dynamic model and conduction of its analysis and simulation 2. Establishment of dc-link voltage control mechanism 3. Establishment of system evaluation standard and standard installation procedure
Division Project II DC Load	Sub-project 6 – Prof. Yuan-Chih Chang and Prof. Tze-Yee Ho Title: Dynamic Analysis, Control and Filter Design for DC Load and Appliance	1. Cooperated with manufacturers for implementing dc appliance and control 2. Conducting dynamic analysis and filter design
Division Project III Energy Storage Equipment	Sub-project 7 – Prof. Shyh-Leh Chen and Prof. Yuan-Chih Chang Title: Development of Flywheel Energy Storage Equipment	1. Realization of flywheel magnetic levitation control algorithm 2. Design and implementation of motor/generator driver
	Sub-project 8 – Prof. Yung-Chun Wu Title: Development of Energy Equipment with Li-Ion Battery	1. Design and implementation of fast charger/discharger 2. Establishment of fast regulation control mechanism for dc-link voltage
Division Project IV Monitoring and Control	Sub-project 9 – Prof. Yu-En Wu and Prof. Chih-Lung Shen Title: Development of Energy Management System for dc Microgrid and System Optimization	1. Establishment of communication interfacing, system operation and management mechanism 2. Evaluation of an optimal system structure and scale

System Configuration of DC Microgrid

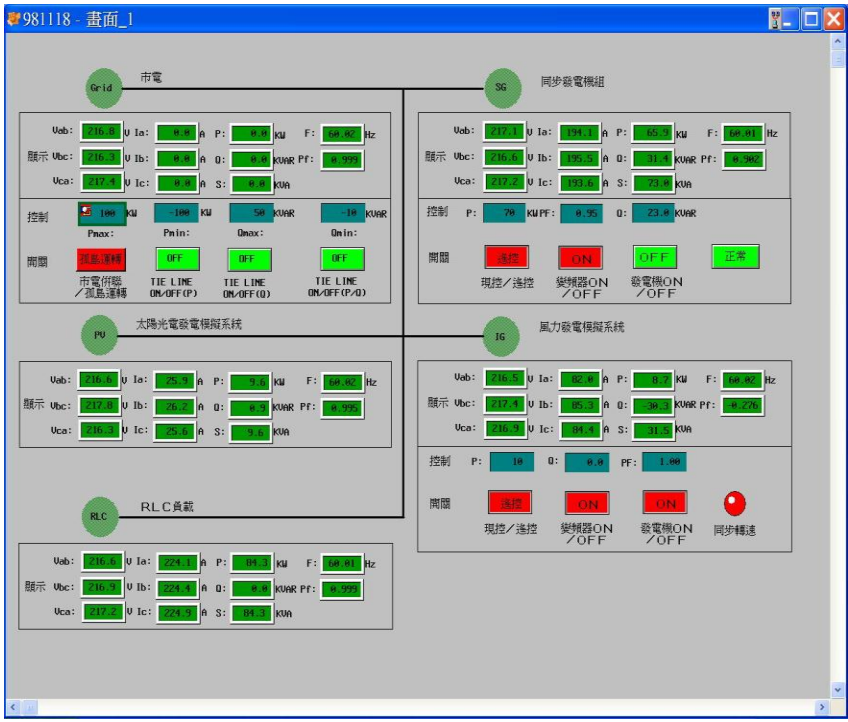


ITRI Microgrid Test Field

- Build a microgrid monitor system for the tests of grid connected and disconnected.
- Build a MGCC to monitor and control DGs and loads to stabilize the operation of microgrid in grid-connected & islanding modes.



Microgrid experiment system



Microgrid monitor panel

ITRI Microgrid Test Field

Specifications for microgrid experiment system

(1) 3-phase synchronous generator

額定輸出容量	153 kVA
額定輸出電壓	220 V
額定轉速	1800 rpm
極數	4
頻率	60 Hz
轉子型式	凸極式

(2) 3-phase induction generator

額定輸出容量	110 kW
額定輸出電壓	220 V
額定轉速	1800 rpm
極數	4
頻率	60 Hz
轉子型式	圓柱式

(3) 3-phase induction motor

額定輸出容量	110 kW
額定輸出電壓	440 V
額定轉速	1800 rpm
極數	4
頻率	60 Hz
轉子型式	圓柱式/繞線式

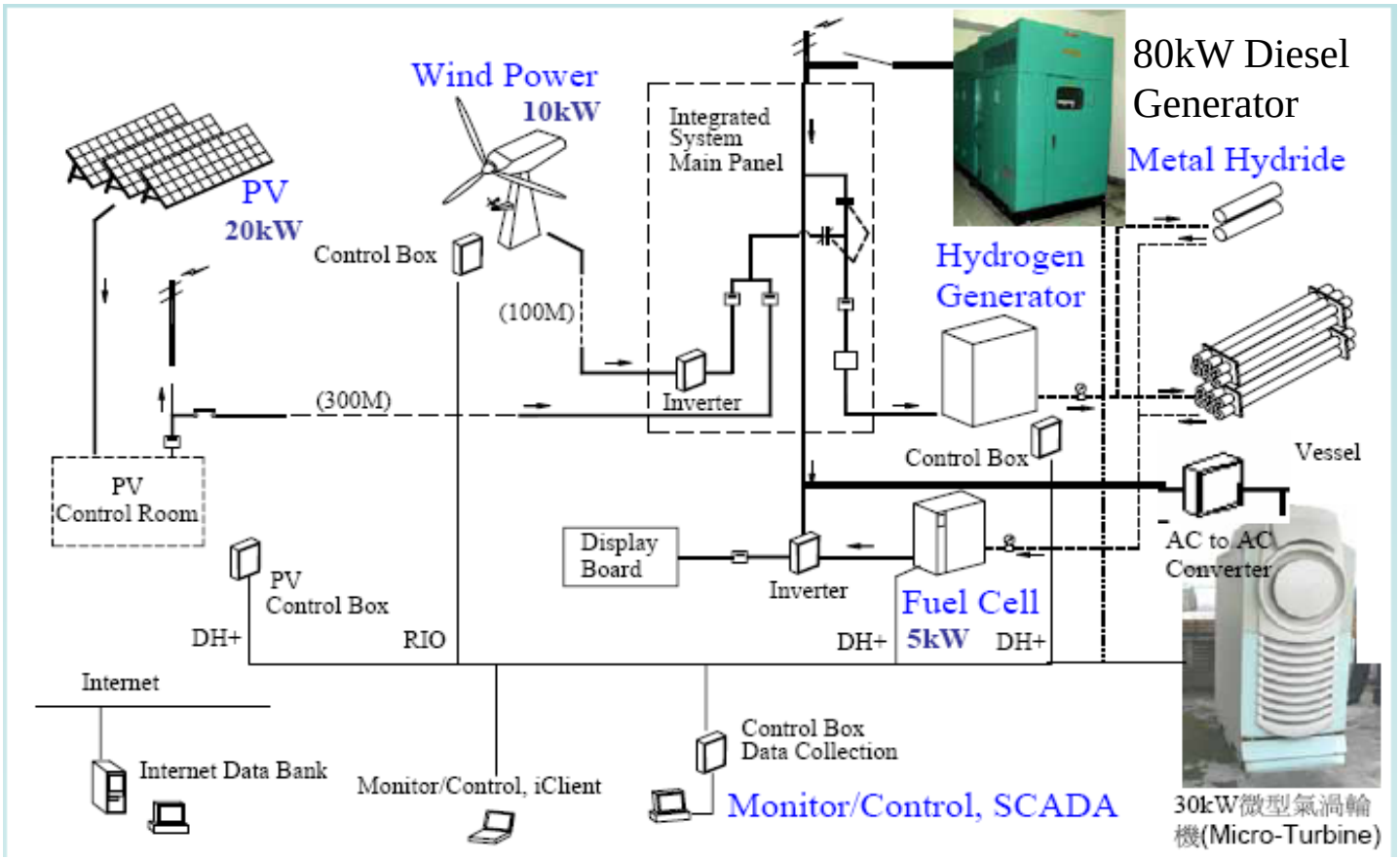
(4) 3-phase PV system

額定輸出功率	100 kVA
額定市電電壓	220 V
最大電流	262 A
額定市電頻率	60 Hz
功率因數	>0.99(額定輸出時)
電流總諧波失真率	<5% (額定輸出時)

(1) 3-phase RLC load

額定輸出電壓	220 V	電感額定輸出容量	100kVAR
電阻額定輸出容量	100kW	電容額定輸出容量	100kVAR

Taipower Microgrid Test Field



Shu-Lin Microgrid test field will be performed from 2011.

Thank You for Your Attention!