Asia-Pacific
Economic Cooperation

APEC Low-Carbon Model Town Energy Management System Development and Application Research

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APEC Low-Carbon Model Town
Energy Management System Development and Application Research

Produced By:
Shandong Sacred Sun Power Sources Co. ltd

Produced For:
Asia Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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APEC Low-Carbon Model Town

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Summary

APEC region, as one of the most important regions of energy production and consumption, is confronted with critical energy supply and demand pressure due to large-scale urbanization, especially in the developing economies.

As a result, it is a common challenge for all APEC member economies to vigorously develop recyclable energy, advocate energy-conservation and emission reduction technology and optimize energy management system. This will also bring new job opportunities and economy development for APEC region. At the meantime, enormous market demands and strong innovation potential of APEC region will accelerate the development of global Energy Internet, thus leading us to a dramatic energy reformation era.

Recently, more and more APEC economies are taking active role in Low-carbon Model Town (LCMT) Project, during construction of which, energy management is supposed to be improved by optimal energy solutions developed through analysis and examination of energy production, transmission, distribution and recycle. It is of great significance to design and develop energy management system and set a basic platform for Energy Internet based on a digital, visual and intelligent management.

The establishment of LCMT energy management system (EMS) can promote scientific management and optimal allocation of energy, enhance energy consumption management, and increase energy consumption efficiency of APEC LCMT.

Several energy management system application best practices of different scale, sector and technical methods are analyzed in this report, including energy management systems of the Yanqi Lake project, the 2014 APEC Economic Leaders' Meeting Venue. These systems, feasible in technology, reasonable in economy and acceptable in environment and society, can effectively reduce loss and consumption in each step from energy production to energy utilization, providing a more effective and economy energy utilization method and improving energy economic benefit.

Energy Internet is a kind of network based on current grid, integrating a large number of

distributed renewable energy power system and distributed energy storage system, with advanced power electronic and information technology to realize bilateral flow of energy and information. Low-carbon urban energy management system is one of the fundamental units of future Energy Internet.

Under above background and analysis, the development of EMS shows the following features:

- Two Replacements of Energy Supply Sector

'Clean replacement' and 'electricity replacement' are required to deal with numerous challenges including energy sustainability, environment pollution and climate change that confront long term development of APEC region.

- Comprehensive Popularization of EMS

To realize efficient utilization, energy saving and emission reduction of conventional energy, as well as reasonable utilization of combined conventional energy and new energy, requires constant improvement of EMS.

- Interactive Management of User Side

By interactive management of user side, users actively participate in energy management while suppliers providing high-quality, convenient and value-adding energy service.

- Establishing Energy Trade Platform and Flexible Exchange Mechanism

In addition to international petroleum and other conventional energy trade platform, regional energy trade platform and mechanism is of increasing importance with popularization of EMS.

- Joint Development of Energy Internet

With Energy Internet, users can interact and communicate with energy market via customized energy utilization mode, thus realizing maximal value, they can carry out better management of demand and reduce energy utilization cost together with energy producer. All these will promote energy system within APEC region towards green, economic and efficient system.

1 Brief Introduction of the study

1.1 Background Information

As the residing, working and living center of human beings, cities and towns are not only primary districts of energy consumption, but also could be core areas for energy production, transmission and storage in near future, with constant development of technologies, especially generalization of solar photovoltaic and other distributed energy systems. This will bring far-reaching impact on future energy supply and demand as well as personal lifestyle.

With accelerating global urbanization, outdated energy system will waste large amount of resources and capital on one hand, and bring devastating effects to urban environment on the other. For example, some cities and towns of APEC developing economies are hit by more and more serious haze, harming not only their citizens' health, but also the attraction and competiveness related to investment, employment, and tourism, etc.

In order to cope with energy crisis and challenges during urbanization, APEC economies spare lots of efforts to study, develop and advocate new and renewable energy technology and management system, especially extending application of wind power, solar photovoltaic and other renewable energy.

The project mainly focuses on power system in cities and towns. Compared to thermal power, hydropower and other conventional energy resources, wind power, photovoltaic and other renewable energy sources can be largely installed through highly efficient and economic energy management system established by deep integration and constant innovation, or even global Energy Internet. The future Energy Internet, similar to the current Internet, can be used by town folks, enterprises and even each household to produce energy, use energy and share energy with other users.

To develop energy management system and set up regional even global Energy Internet requires not only integration of energy webs and Internet technologies, but also support from corresponding intelligent technologies and energy storage technologies. Intelligent technologies mentioned above are intelligent grid data collection, analysis and diagnosis, grid interactive terminal, grid demander response, distributed energy micro grid, and energy management system, and energy storage technologies including distributed energy storage technology and centralized energy storage technology, etc.

This project emphasizes on the following: field research on different stages of low-carbon town energy produce, energy transmission and storage, distribution as well as energy consumption, systematic summary and research on Energy Internet, energy management system storage technology; probing into means and methods of constantly optimizing integrated planning, design and layout of energy, and sharing collected cases and materials with APEC economies by this report.

1.2 Main Research Tasks

1.2.1 Field Research on Energy Management System

To collect power generation by different energy resources through studies on different parts of LCMT energy system in APEC region, especially growing distributed energy systems as solar photovoltaic, combined cooling heating and power, and wind resources, etc.; investigate best practice projects of energy transmission and storage, and latest standard, technology, innovation, products and equipment of energy transmission and storage; research optimal plan and technological controlling methods of energy distribution; probe into modified energy consumption plans and issues related to energy recycling.

1.2.2 Energy Management System Current Status Analysis

The report will briefly introduce technologies and application status of energy management system of APEC economies, and analyze advantages and disadvantages of different energy management system, as well as the significance of energy management system application. With energy management system, secure and efficient access and utilization of distributed renewable energy can be realized, and interactive integration as well as efficient, comprehensive and economic utilization of various energy forms can be achieved.

1.2.3 Energy Management System Evaluation Mechanism

Experience of energy management system in APEC region will be summarized to establish energy management system evaluation mechanism, which works via user demands analysis, system establishing conditions, project designing, technical solution selecting, software and hardware selection and operation, and energy-conservation effect comparison, etc to carry out evaluations on the function and efficiency of energy management system.

1.2.4 Energy Internet Development

The report will summarize current situation of intelligent and energy storage technologies of Energy Internet, research functions of significance of Energy Internet, and analyze developing trend of Energy Internet and its importance for future energy transformation. The Energy Internet, while realizing interconnection and interworking of energy system, can improve the utilization ratio of clean energy by its specific intelligent scheduling, thus promoting the energy transformation of APEC region.

1.2.5 Best practices

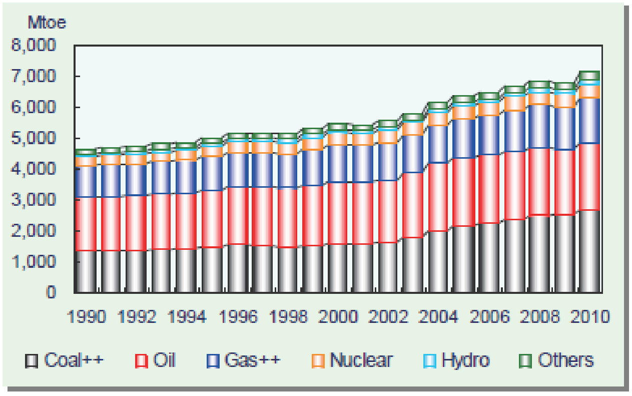
The report will provide detailed introduction about the energy management system of Yanqi Lake, the main venue of the 2014 APEC Economic Leaders' Meeting, including various aspects as renewable energy application, energy conservation, and environment protection. At the meantime, some other best practices and pilot projects of APEC economies and some European countries are also introduced for reference.

2 Energy System of LCMT

2.1 APEC Region Energy Overview

2.1.1 Increasing Energy Supply and Consumption

As a major district of global energy production and consumption, APEC region witnesses increasing energy supply and consumption, especially that of fossil energy, which occupies a relatively large proportion compared to European developed countries and regions, causing greater pressure on air, water, earth and other environment factors of entire Asian Pacific area. In 1980, areas haunted by acid rain in China is less than 10 percent of the entire land, while today, lots of areas in China are confronted with this problem.



Mtoe

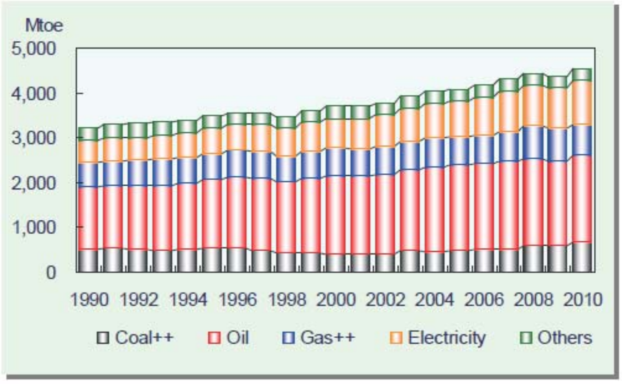
	1990	1995	2000	2005	2009	2010
Coal++	1,359.9	1,485.8	1,571.7	2,150.8	2,519.0	2,687.4
Oil	1,751.6	1,820.2	2,009.9	2,202.0	2,114.1	2,149.8
Gas++	998.5	1,085.8	1,197.5	1,263.6	1,382.4	1,483.4
Nuclear	283.1	344.7	389.2	415.9	424.4	433.2
Hydro	94.7	111.1	111.0	128.5	148.6	156.5
Others	146.6	157.6	173.2	187.2	198.3	232.4
Total	4,634.4	5,005.2	5,452.5	6,347.9	6,786.8	7,142.7

Share (%)

	1990	1995	2000	2005	2009	2010
Coal++	29.3	29.7	28.8	33.9	37.1	37.6
Oil	37.8	36.4	36.9	34.7	31.2	30.1
Gas++	21.5	21.7	22.0	19.9	20.4	20.8
Nuclear	6.1	6.9	7.1	6.6	6.3	6.1
Hydro	2.0	2.2	2.0	2.0	2.2	2.2
Others	3.2	3.1	3.2	2.9	2.9	3.3

Fig. 2-1 Total primary energy supply in APEC

（Source：APEC Energy Handbook 2010）



Mtoe

	1990	1995	2000	2005	2009	2010
Coal++	519.0	551.5	423.4	492.1	599.6	684.6
Oil	1,388.0	1,520.9	1,723.9	1,910.5	1,887.9	1,939.7
Gas++	551.0	585.3	633.5	627.3	735.8	692.1
Electricity	502.2	563.7	674.3	806.6	903.7	973.1
Others	275.9	272.3	273.7	264.1	258.3	272.1
APEC 21	3,236.1	3,493.7	3,728.7	4,100.5	4,385.2	4,561.6

Share (%)

	1990	1995	2000	2005	2009	2010
Coal++	16.0	15.8	11.4	12.0	13.7	15.0
Oil	42.9	43.5	46.2	46.6	43.1	42.5
Gas++	17.0	16.8	17.0	15.3	16.8	15.2
Electricity	15.5	16.1	18.1	19.7	20.6	21.3
Others	8.5	7.8	7.3	6.4	5.9	6.0

Fig. 2-2 Total final energy consumption in APEC

（Source：APEC Energy Handbook 2010）

Since China’s urbanization and industrialization requires more and more energy, carbon emission and haze problems produced accordingly is becoming more prominent. Therefore, China now is vigorously advocating application of solar photovoltaic and other renewable energy in urban areas. At the meantime, grid companies also carry out researches on the feasibility of regional Energy Internet based on energy management system.

Tab. 2-1 China Energy Demand Expectation by Institutions Home and Abroad

Institution		Situation	2015	2020	2025	2030	2035	2040	2050
International	IEA,2008	Baseline	41.5	46.9	51.8	55.5			
		Baseline	40.7	/	/	54.6			
	IEA,2007	Policy	39.2	/	/	46.5			
		High Speed Growth	44.8	/	/	67.0			
	IEEJ,2007	Baseline	/	36.0	/	44.7			
		Advanced Technology	/	30.7	/	35.5			
	Greenpeace and EREC，2007	Energy Revolution	21.3	23.4	25.2	26.0			
National	SIC and DRC of the State Council (2007)	Baseline		43.2		52.3		59.2	63.0
		Low Speed Growth		38.0		43.9		49.0	51.5
		High Speed Growth		49.0		62.7		72.9	79.1
	NDRC ERI Energy Conservation Priority Research Group (2007)			36.8		41.4			
	NDRC ERI Low Carbon Development Research Group (2008)	Energy Conservation		47.7			58.5		66.9
		Low Carbon		39.6			48.4		55.6
		Strengthened Low Carbon		38.5			46.0		50.2

Tab. 2-2 2030 China Energy and Electricity Demand Forecast

Institution / Benchmark Year	Situation	Primary Energy Demand (100 Million Standard Coal)	Total Power Generation Demand (Trillion kWh)
Base Period, 2005	Reference Situation	54.6	8.5
	Optional Policy Situation	46.5	7.4
	High Economic Growth Situation	67.0	N/A
IEA, 2008 Base Period, 2006	Reference Situation	55.5	8.2
IEEJ Base Period, 2005	Reference Situation	44.7	6.4
	Technology Improvement Situation	35.5	5.3
NDRC ERI – 2050 Circumstance Research; Base Period, 2005	Baseline Situation	57.78	8.2
	Low Carbon Development Situation	43.37	6.7
China Energy Medium and Long-term Development Strategy Research Base Period, 2007	Program	N/A	9.0
	High Speed Development Plan	N/A	10.4
	Low Speed Development Plan	N/A	8.1

Haze has become a major challenge confronting most APEC developing economies, which is often seen on global PM 2.5 statistical data ranking list. While harming their citizens' health, reducing the attraction and competiveness related to investment, employment, and tourism, etc., it also brings greater environment pressure on surrounding area with atmospheric flow.

Fig. 2-3 The haze of Beijing, China

2.1.2 Energy Restructuring

Compared to the energy structure of APEC economies in past 20 years in which conventional resources as coal, fossil oil and natural gas occupy a large part, the greatest change lies in the fact that more and more economies are taking active part in developing renewable energy such as wind power and solar photovoltaic, etc. By the year 2020, China plans to realize 200GW installed wind capacity, and 100GW solar photovoltaic. Renewable energy including wind and photovoltaic requires higher managing standard for energy supply, transmission, and consumption compared to conventional energy.

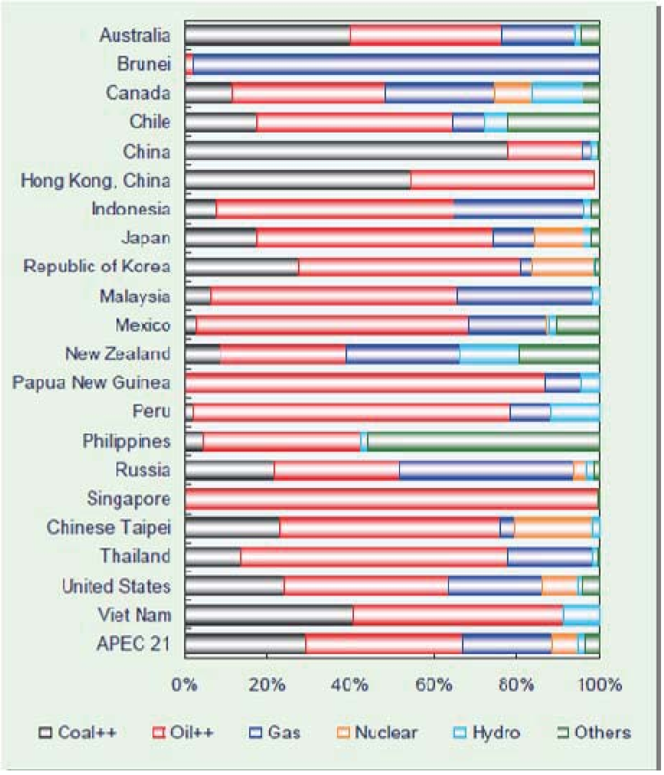


Fig. 2-4 Primary energy mix by economy 1990

（Source： APEC Energy Handbook 2010）

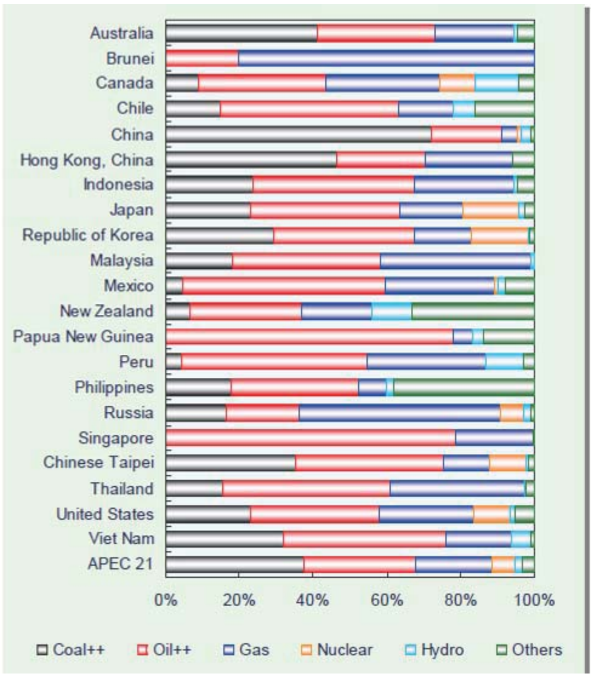
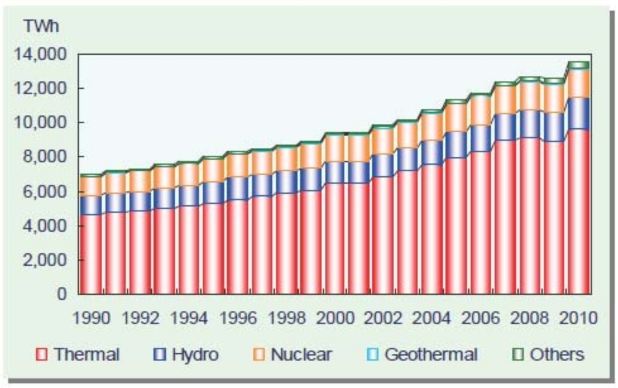


Fig. 2-5 Primary energy mix by economy 2010

（Source： APEC Energy Handbook 2010）



TWh

	1990	1995	2000	2005	2009	2010
Thermal	4,629.2	5,272.1	6,451.0	7,967.8	8,871.4	9,591.7
Hydro	1,101.0	1,291.7	1,290.4	1,493.6	1,726.7	1,820.5
Nuclear	1,087.3	1,322.7	1,493.4	1,595.9	1,628.5	1,662.3
Geothermal	31.5	34.1	43.4	47.4	51.1	52.9
Others	113.4	100.6	115.0	170.0	288.3	342.5
Total	6,962.5	8,021.2	9,393.1	11,274.7	12,566.1	13,469.9

Share (%)

	1990	1995	2000	2005	2009	2010
Thermal	66.5	65.7	68.7	70.7	70.6	71.2
Hydro	15.8	16.1	13.7	13.2	13.7	13.5
Nuclear	15.6	16.5	15.9	14.2	13.0	12.3
Geothermal	0.5	0.4	0.5	0.4	0.4	0.4
Others	1.6	1.3	1.2	1.5	2.3	2.5

"Others" comprises power generated from renewable energy.

Fig. 2-6 Electricity power generation by type APEC 21

（Source：APEC Energy Handbook 2010）

2.1.3 Rapid Development of Energy Management System and Energy Internet

More distributed energy like wind power and solar photovoltaic connected to energy system is followed by stronger demanding for application of energy management system.

The developing trend of APEC region energy management system is to improve comprehensive investing efficiency of energy networks so as to further optimizing energy utilization; to realize interactive management of user side so that users can actively participate in energy management and suppliers can provide energy services of higher quality, convenience and added value; to establish energy exchanging platform and flexible exchanging mechanism, forming an energy market that coordinates utilization of multi-energy; to guarantee clean energy as main force of energy market and significantly expand supply ratio of renewable energy; to set up user side system so that users can have sufficient access to energy industry system, thus transforming towards green, economic and high-efficient energy utilization; to constantly improve operation standard of energy system so as to realize efficient utilization of conventional energy system and emission reduction. Energy Internet that enables bilateral flow of energy and information is supposed to be discussed and established at a wider scope gradually.

2.2 LCMT Energy Planning

Increasing numbers of APEC cities and towns start paying attention to research and planning of local energy, analyzing and forecasting energy consumption demand and optimizing on spatial arrangement of energy supply. Combined heat and power generation is suitable for hospitals, colleges and universities, and commercial and residential building complex of higher heat density located in town center; while the industrial park, main energy-consuming district of town, could be equipped with renewable power generation including solar photovoltaic power station, wind farm, garbage power plant, and biomass power generation, etc. As for suburbs where population and housing density stays low, distributed energy system as small-size photovoltaic system and wind-solar hybrid system; whereas the back-land of rural areas will benefit from bio-fuel such as biogas power generation, etc.

2.3 LCMT Energy Production

The construction of low-carbon town, which is advocated by APEC economies to deal with environment pollution and energy crisis, requires wide employment of renewable energy, especially photovoltaic, wind, wind-solar hybrid system, combined cooling heating and power, and hydroelectricity, etc.

2.3.1 Solar Photovoltaic

APEC region is the largest region as for global photovoltaic producing, application and research, with China, Japan, the U.S. and other economies ranking top of global photovoltaic installation list and remaining high speed in further growth.

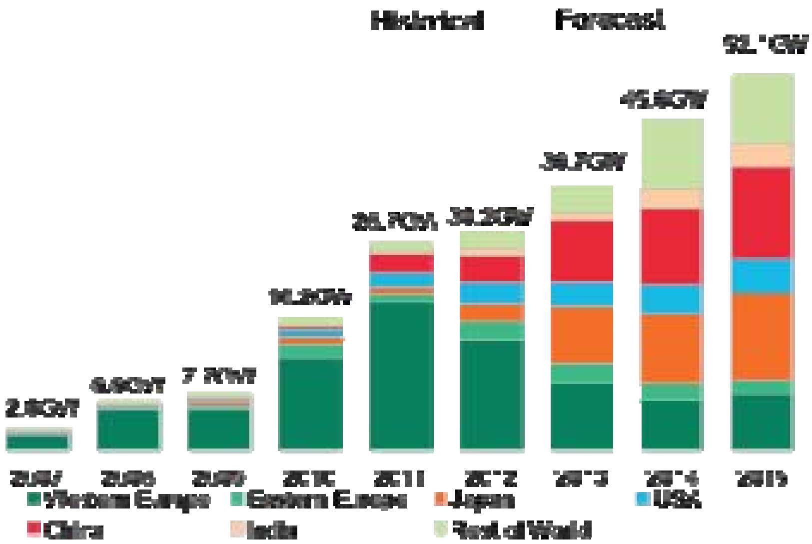


Fig. 2-7 Global PV new installed capacity in 2007~2015

（Source：Bloomberg New Energy Finance）

What follows improving technology and increasing production efficiency is rapidly reducing of photovoltaic system installation cost, which is about $1 per watt in some APEC economies, already reach grid parity. With developing experience of European countries such as Germany in the past years, and the devastating impact of Fukushima nuclear accident on global nuclear energy, photovoltaic could become the most important energy supply form for APEC economies in this century. Distributed photovoltaic system specifically will be the core solution to realize low-carbon town development during the process of urbanization.

Polycrystalline silicon or thin film components can be selected as photovoltaic system component elements according to different application environment, while the application of micro-inverter and other products ensures more secure photovoltaic system and easier maintenance and management. Besides, the application of photovoltaic will accelerate constant innovation and employment of electric bicycle, direct-current grid, and micro-grid, etc. in the future. The combination of photovoltaic system and electric vehicle, electric bicycle, as well as personal mobile power storage devices will witness a more flexible, efficient, economic and sustainable new energy system in future.

Fig. 2-8 Residential Photovoltaic System

Fig. 2-9 Photovoltaic system located on fishpond

APEC economies made valuable efforts to promote solar photovoltaic application, one of them is the Solar Decathlon initiated and hosted by U.S. Department of Energy. Solar Decathlon is an award-winning program that challenges collegiate teams to design, build and operate solar-powered houses that are cost-effective, energy-efficient and attractive. All energy needed for the operation of solar houses is provided by solar devices during the competition. The houses are evaluated in 10 subjective and objective contests including architecture, market appeal, engineering, communications, solar application, comfort zone, hot water, appliances, home entertainment, and energy balance to examine their energy conservation, building physical environment control and energy self-supplying performance. Therefore, the competition is named Solar Decathlon after Olympic Decathlon competition. It is also praised as Olympic of solar industry.

Fig. 2-10 Solar Decathlon China 2013

From August 2nd to 13th, 2013, Solar Decathlon China 2013 was held in Datong, Shanxi Province, with 22 collegiate teams with students of 35 colleges from 13 different countries, including the China, Australia, Iran, Israel, Malaysia, Singapore, Sweden, U.K., U.S., etc. The competition put the latest technology and production innovation into practice, demonstrating various development route of photovoltaic application technology and setting favorable examples for photovoltaic application in APEC low-carbon cities and towns.

2.3.2 Wind and Wind-solar Hybrid System

The installed capacity of wind power, a mature renewable energy application technology, is increasing rapidly with over 70GW installed capacity in China only. Wind power can be used in both remote area and towns and cities as well. For example, Donghai Bridge Offshore Wind Farm Project with 100MW installed capacity is built in Shanghai, China with its coastal advantage.

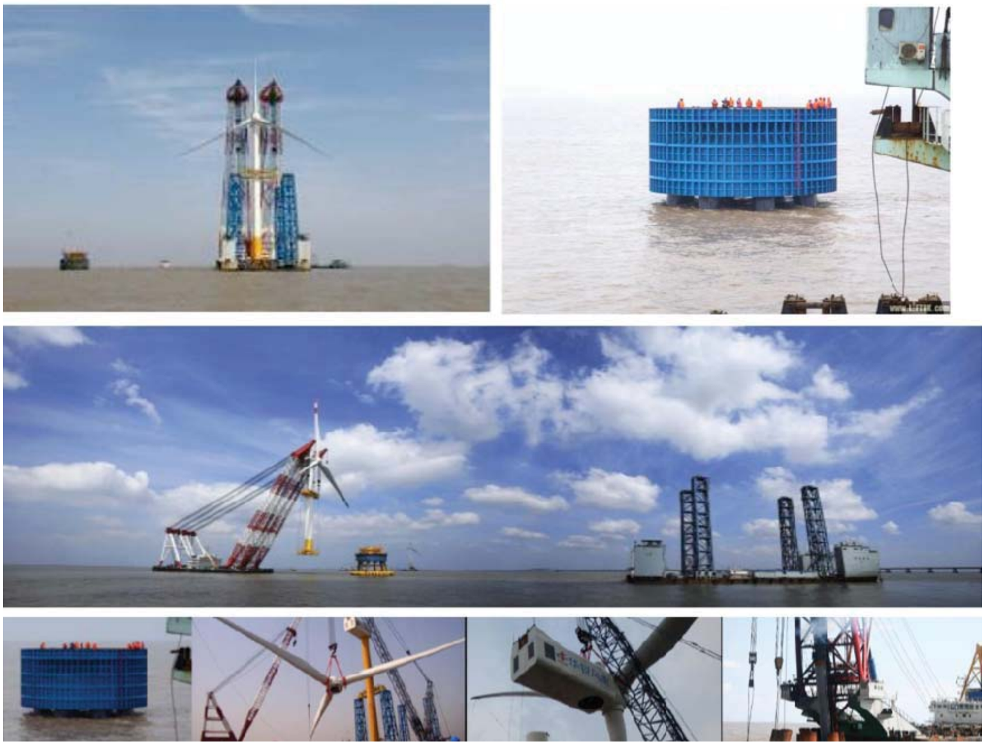


Fig. 2-11 Donghai bridge offshore wind farm demonstration project

Wind-solar hybrid system solved part of the problem caused by resources and weather restriction for wind power generation or solar photovoltaic, through comprehensive utilization so that they can complement each other in relation to diurnal change and season variation, which improves stability and reliability of power supply system and reduces equipment cost by a large margin at the same time.

Wind-solar Hybrid System is suitable for districts of lower population density to use household electrical appliances with aggregate capacity of no more than 500W, such as color TV, energy saving lamp, satellite TV antenna receiver, audio device, and fan, etc. Typical configuration of household off-grid system is as follows Tab.2-3:

Tab. 2-3 Typical configuration of household off-grid system

Name	Type	Unit	No.	Remarks
Wind Driven Generator	D3-1/9	set	1	DC28V
1kW tower	Stay Cable	set	1	
Photovoltaic Components	200Wp/24V	set	1	Polycrystalline
Component Holder	Auxiliary	set	1	
Wind-solar Hybrid Control Inverter	600VA	set	1	
Storage Battery	200Ah/12V		4	Airtight Valve Regulated Lead Acid Battery

The establishment of household system can satisfy power supply of above-mentioned devices. Moreover, the system is able to guarantee device power consumption of 3 cloudy days at the condition of full storage battery, thus reducing supposed pressure on the grid.

Fig. 2-12 Wind turbine and wind farm

Fig. 2-13 Intertidal zone wind farm

Fig. 2-14 Mini-size wind power system on boat

Wind-solar Hybrid System can reasonably allocate system capacity according to users' power consumption load and resource condition, thus ensuring reliable power supply and reducing power generating cost at the same time. Therefore, optimized system designing plan can be made to satisfy user demand regardless of environment and power consuming requirements. Wind-solar hybrid system is the most reasonable off-grid system contributed to its reasonable resource allocation, designing plan and cost effectiveness, which guarantees high reliability of this system.

Fig. 2-15 Wind-solar hybrid system

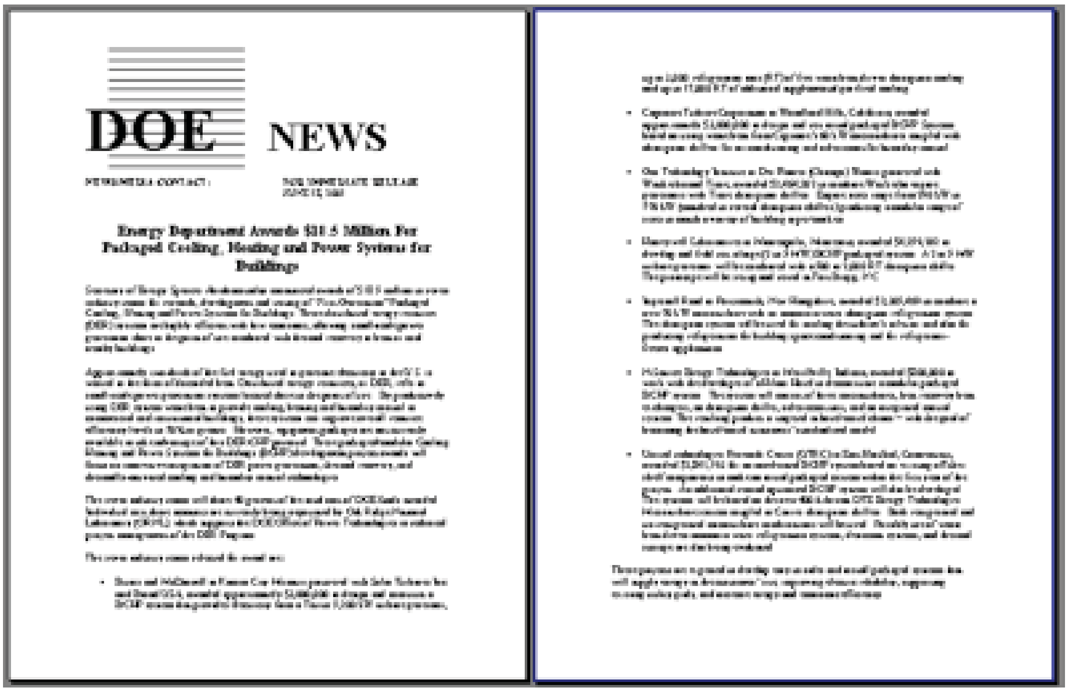
Fig. 2-16 Wind-solar hybrid system

Large-scale development of wind power requires not only technological improvement and cost reduction of this industry, but also constant coordination of wind power, other power source and grid construction and operation, further construction of intelligent grid system as well as power exchange market optimization. The future of wind power application will be brighter with popularized utilization of energy management system, energy storage and other advanced electric system.

2.3.3 Combined Cooling Heating and Power

Combined cooling heating and power (CCHP) means to produce power by operating gas power generation devices including gas turbine, micro-gas turbine and oil-electric engine driven by natural gas as main fuel so as to satisfy users' demand, with the waste heat produced after power generation being collected by waste heat collecting devices to supply heat and cooling. In this way, primary energy ratio can be significantly increased, thus realizing gradient utilization of energy. Moreover, electricity can be provided as energy complementation, thus increasing economic benefit and efficiency of the whole system.

With gradient utilization of thermal energy and combined heating cooling and power, heat power of natural gas can be sufficiently employed with a comprehensive energy utilization ratio of more than 90%. At the meantime, cost of heat supply based on natural gas can be reduced so that some of the cost can be used for electricity fees to alleviate pressure on operation cost. APEC economies lay great emphasis on this technology. As early as June 18th, 2001, U.S. Department of Energy (DOE) declared to award $18.5 million for 7 combined cooling heating and power systems for building, the concrete content is as shown in Fig.2-17.


DOE NEWS

Energy Department Awards $18.5 Million For Packaged Cooling, Heating and Power Systems for Buildings

Fig. 2-17 DOE of USA promulgated the file of establishment 7 BCHP project

(Source: DOE, USA.)

During the process of low-carbon economic and social development as well as energy restructuring of low-carbon towns, big and medium-size combined cooling heating and power system are widely developed in industrial park with concentrated heat users to further stimulate heat supply reformation of big power stations and their heat supply for perimeter regions, thus improving energy utilization ratio. Meanwhile, regional combined cooling heating and power will be vigorously developed in comprehensive business district, industrial area and other places requiring concentrated energy consumption, including hospitals, hotels, transportation junctions, shopping malls and business buildings, etc. with its outstanding advantages on energy transformation efficiency, combined cooling heating and power is supposed to show superiority in energy acquisition, energy conservation and emission reduction during LCMT construction.

Changsha Huanghua International Airport Terminal 2, with a covered area of 154 thousand square meters, handles about 15.2 million people per year. On July 19th, 2011, its CCHP center is put into operation, supplying power, air conditioning as well as cold and hot water for terminals stably.

Main indicators of CCHP center are: electricity power is integrated into 10.5KV transformer substation of the airport to realize grid-connected operation; the installed power-generating capacity is 2320KW, with wasted heat (400℃ exhausted gas and 95℃ cylinder liner water) being incorporated into Yuanda BZHE200 complemented combusting multi-energy water heater and chiller machine in a seamless way; wasted heat of power generation can satisfy 40% air conditioning demand of the terminal for a year; peak load regulation devices are 1 direct-fired machine and 2 centrifugal refrigeration machine set; water cold and heat storage is to be used to increase utilization rate of generator set and wasted heat; primary investment is 10-20% lower than project of the same kind; comprehensive efficiency of the system reaches 76%; gas and electricity price ration stands at 1.22 and incremental investment payback time is 9 years; 8,100 tons CO2 emission will be reduced per year.

Fig. 2-18 Changsha Huanghua international airport terminal 2 CCHP Project

2.3.4 Hydroelectric Generation

Hydroelectric Generation is fit for towns surrounded by rivers, lakes or sea. Hydropower station, according to different energy resources, can be divided into conventional hydropower stations as dam, water diversion and hybrid hydropower stations, pumped-storage hydropower station that regulates peak and lowest load of electric system, water-solar (photovoltaic) hybrid power station that comprehensively utilize various energy forms, and ocean energy stations including tidal power stations and wave energy stations that generate power by water mechanical energy of ocean energy. Hydroelectric generation is also one of the possible parts of low-carbon town energy system.

Fig. 2-19 Hydroelectric generation

2.4 LCMT Energy transmission and Distribution

Most part of LCMT energy transmission is electricity transmission. With development of electricity transmission and distribution technology and distributed energy as photovoltaic, more technologies regarding energy transmission and distribution are showing up.

2.4.1 Direct Current Transmission and Alternating Current Transmission

By the end of the 19th century, scientists are divided into two different parties concerning the utilization of direct current transmission or alternating current transmission. As a result of these debates, alternating current transmission stimulated grand development of electric system with its networking and convenient boosting advantages.

By now, almost all APEC economies choose combined direct and alternating current transmission grid in large scale. With voltage classes rising from 10KV, 110KV to500KV, and even 1000KV, power grid increasing in scale, corresponding direct and alternating current transmission is developing as well, with high integration of these two technologies in engineering application.

Direct current transmission is free from the stability issues haunting alternating current transmission, and enjoys low cost and minimal waste compared to alternating current transmission under same power degree. Besides, direct current transmission is benefited with several other advantages as less losses, and little communication interference, etc.

From the perspective of distribution network, load of future power distribution network relies mostly on direct current transmission. For example, electric vehicle, and lots of information devices as computer and microprocessor, communication system device, intelligent terminal, sensor and sensor network, etc., require direct current transmission, and load electromotor, one of the most important parts of power consumption, can enjoy lower cost and higher efficiency of its driving system with direct current transmission.

2.4.2 Grid-connected Operation and Off-grid Operation

2.4.2.1 Grid-connected Operation

Grid-connected operation means to transfer electricity by connecting power generated like photovoltaic, wind and other distributed energy to the grid, which has the following advantages:

- Saving the process of energy storage with storage battery;
- The inverter will become more stable and reliable contributed to the developing inverter manufacturing technology;
- Power generation system works with maximum power all the time to generate power, which will all be connected to the grid, thus enhancing power generating efficiency;
- In addition to benefiting the grid, distributed power generation system can supply power to local users, alleviating transmission and allocation pressures on the grid.

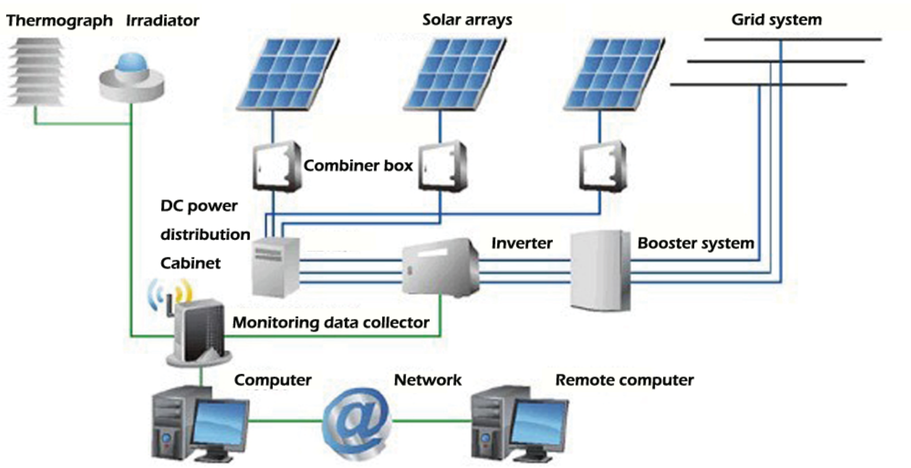


Fig. 2-20 Photovoltaic grid-connected system structure

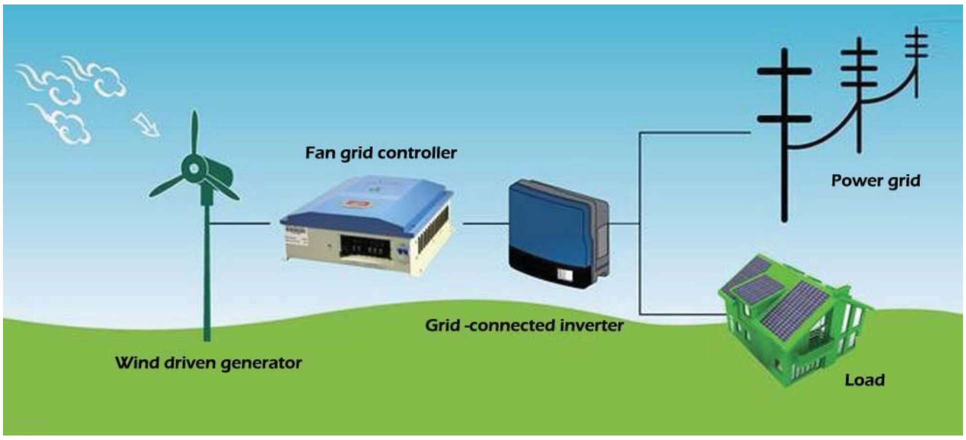


Fig. 2-21 Wind power grid-connected system

2.4.2.2 Off-grid Operation

Unbalanced regional economic development in APEC region decides the wide application of off-grid power system, an important solution for areas that have no access to grid or where population density is low.

Off-grid power supply is realized in several forms including small and medium size wind turbine, photovoltaic system, wind-solar hybrid system, wind-solar-diesel hybrid system, water-solar hybrid system, water-wind hybrid system, and solar-diesel hybrid system, etc. Wind-solar hybrid off-grid system, which effectively utilizes natural resources without pollution, can be widely used in sectors including roadway lighting and indicating system, base station, gas station, island, fishing boat, forest fire prevention and security and protection monitoring, etc.

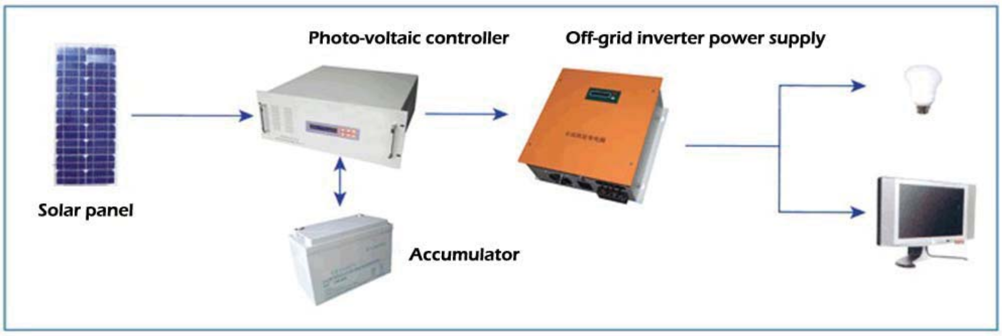


Fig. 2-22 Off-grid power system structure

Fig. 2-23 Photovoltaic off-grid system

2.4.3 Micro-Grid

Micro-Grid is a small-size modular and distributed power supply network mainly based on small power stations of distributed resources or users and supported by distributed power generation technology. It is established by combining end-user power quality management and energy gradient utilization technology.

Micro-grid is a small-size power generation and distribution system made up of distributed energy, energy storage devices, energy conversion devices, related load and monitoring, and protectors. Power supply of micro-Grid is mostly distributed power system with small capacity, including micro gas turbine, fuel cell, photovoltaic module, small size wind turbine and energy storage devices as super-capacitor, flywheel and storage battery, etc., which are connected to the user side, thus guaranteeing low cost, low voltage and few pollution.

The development and extension of micro-grid can stimulate large-scale access of distributed power source and renewable energy, thus realizing highly reliable supply of multiple energy forms. This is an effective way of establishing active power distribution network that leads the transition from conventional grid to intelligent grid.

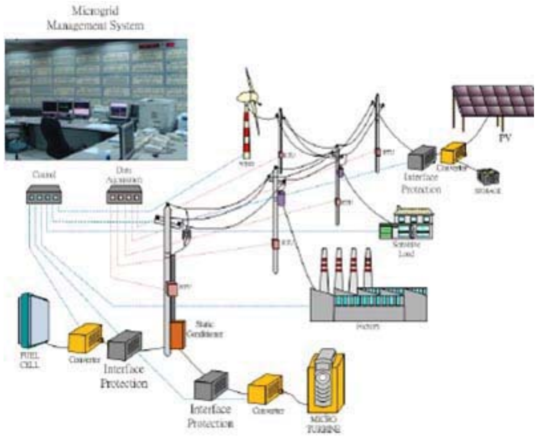


Fig. 2-24 Micro-grid structure

Micro-grid can be divided into three types according different structures: district micro-grid, industrial and commercial micro-grid, and remote area micro-grid.

2.4.3.1 District Micro-grid

The development of district micro-grid is driven by the requirement of off-stream management and integration of renewable energy for power generation. District micro-grid mainly works to reduce greenhouse gas emission, provide multiple energy supply forms for users, and postpone power network upgrade, etc. Moreover, district micro-grid can provide auxiliary services as local reactive voltage support and higher power quality, etc.

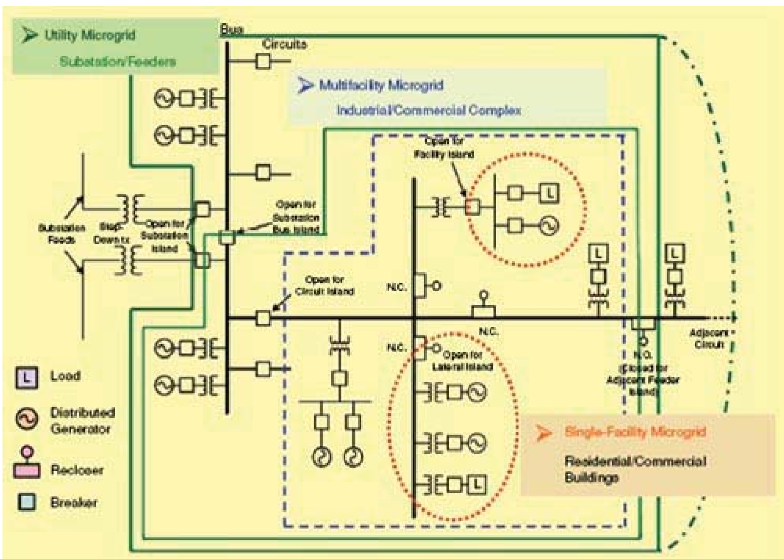


Fig. 2-25 District Micro-grids

2.4.3.2 Industrial and Commercial Micro-grid

Users of industrial and commercial micro-grid users are generally vital load or sensitive load, which requires higher level of power supply reliability and power quality. Industrial and commercial micro-grid can satisfy not only load demand of multiple industrial and commercial districts, including university campus, shopping mall or industrial equipment, but also small-size resident load, such as a group of urban buildings or a condominium can form residential area micro-grid. With convenient and reliable power supply as well as multiple distributed generation power supply customized for users, industrial and commercial micro-grid mainly works to supply power of higher quality, provide different level of power reliability, and integrate CCHP and demand side management (DSM).

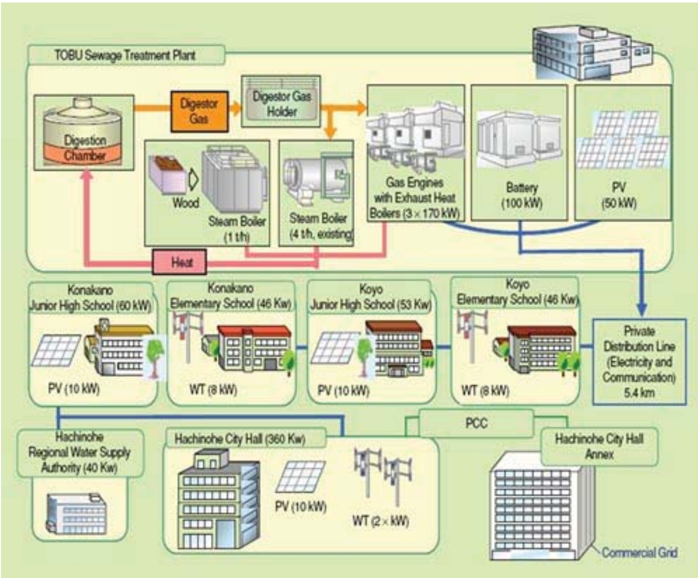


Fig. 2-26 Industrial and commercial micro-grid

2.4.3.3 Remote Area Micro-grid

Remote area micro-grid, with the advantages of integrating renewable energy power generation, reducing greenhouse gas emission and simplifying demand side management, focuses mainly on power supply of remote areas with less consumption of traditional fossil fuel.

With micro-grid supplying power to remote area micro-grid, renewable energy power plant or other distributed generation can be utilized to form isolated grid or independent micro-grid so as to supply power or heat for residents or business users of remote area.

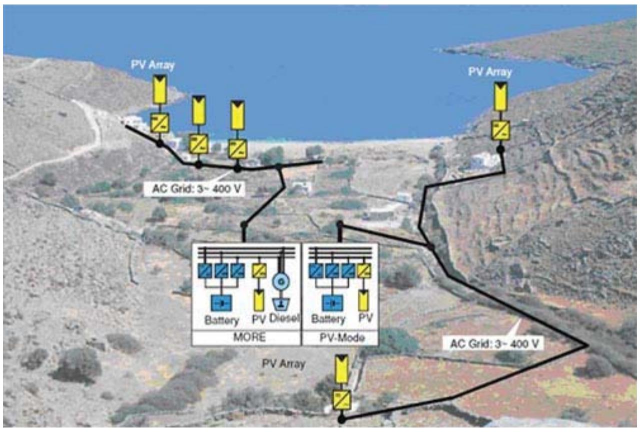


Fig. 2-27 Remote area micro-grids

2.4.4 Smart Grid

Smart Grid based on integrated and high-speed bilateral communication network, is supposed to make grid reliable, safe, economic, efficient, environmentally friendly via application of advanced sensing and measuring technology, equipment technology, controlling method as well as decision support system technology.

The Smart Grid has functions of power distribution network monitoring, feeder fault location, fault isolation, automatic power recover and load control, etc.; establish distributed renewable energy access system with stable connection, effective monitoring and integrated operation of photovoltaic system, wind turbine and energy storage system; set up intelligent electricity utilization system featured by electricity information collection, electric optical fiber, smart building/housing system, electric-mobile charge-discharge system and corresponding service network, and power quality monitoring, etc. as a result, renewable energy consumption ratio of total energy consumption increases significantly.

As a major guarantee for development of new energy, Smart Grid can promote development and consumption of large renewable energy power generation base as well as growth of distributed generation.

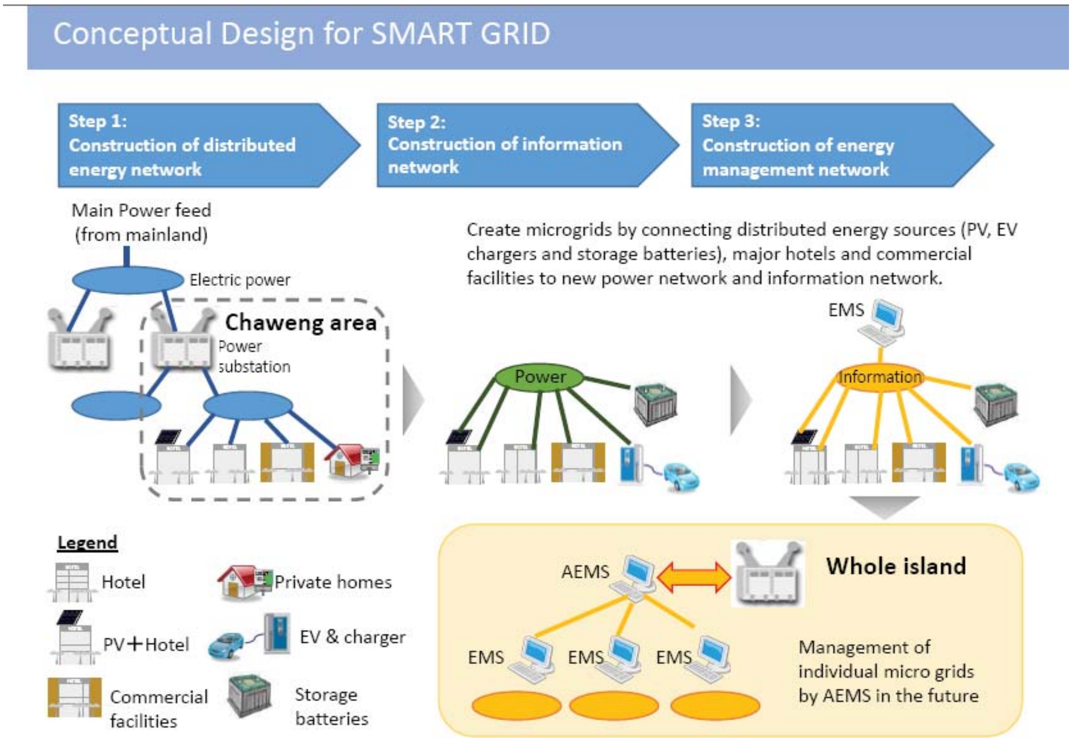


Fig. 2-28 Conceptual design for smart grid

(Source: SAMUI Low Carbon Model Town project introduction, Thailand)

2.5 Energy Storage System

Electricity storage is the main form of the energy storage in LCMT. The electricity producing is continuous, so the balance of electricity producing, transmitting, distributing and consuming must be kept balance at all time. But the load of the electricity system has a huge difference between peak and valley, so a large reserve capacity must be kept, and the operating efficiency of the system device is low.

The energy storage application can shift load peak, increase reliability and stability of the system, reduce requirement of reserve device and power failure damage. Due to the growing renewable energy installation capacity and the continuous development of distributed generation, the electricity storage is becoming more and more important.

The energy storage is one of the essential key technologies to build the modern smart grid even energy internet. By adding an intermediate link into the conventional electricity production system to make the original rigid system become more flexible, it will dramatically increase the safety, reliability, economy, flexibility of the grid operation.

The energy storage application in Electricity system includes peak shifting of grid, system reserve capacity, regulation of the over-load shock, increasing stability of Electricity system, static power compensation, electricity quality improving, distributed generation and power smoothing of renewable energy. The energy storage technology can be divided into mechanical storage, chemical storage and electro-magnetic storage. Mechanical storage includes pumped storage, compressed air storage and flywheel storage. Chemical storage includes lead acid battery and advanced lead acid battery, sodium sulfur battery, lithium ion battery, etc.

2.5.1 Mechanical Storage

2.5.1.1 Pumped Storage

The pumped storage uses water potential energy to store energy, which needs two reservoirs upstream and down stream. When the load is low, the pumped storage device works as a motor to pump the water in the downstream reservoir into the upstream reservoirs to store. When load is high, the pumped storage device works as a generator to produce electricity using the water stored in the upstream reservoirs. Some high dam hydropower station can be used as the pumped storage to dispatch electricity power.

Fig. 2-29 Pumped storage

2.5.1.2 Flywheel Storage

Flywheel storage, where the energy is stored in high speed rotating flywheels as a form of kinetics energy, is constituted by high strength alloy, high speed bearing, bi-directional motor, electricity conversion device and vacuum safety cover. The electricity drives flywheel to rotate in high speed to convert electricity into kinetics energy. When needed, the flywheel slows down and the moter runs as a generator to produce electricity.

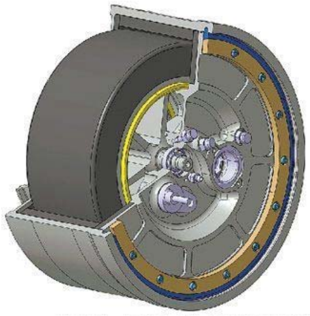


Fig. 2-30 Flywheel storage

2.5.1.3 Compressed Air Storage

The energy storage process of compressed air storage is constituted by two cycle: one is air charging and compression cycle, the other is air discharging and expanding cycle. For energy charging, the bi-directional motor drives the compressor to compress high pressure air into underground storage cave; for energy discharging, the stored compressed air is pre-heated by heater, then burned with fuel in the burning chamber, finally gets into expanding system to generate electricity (drive generators).

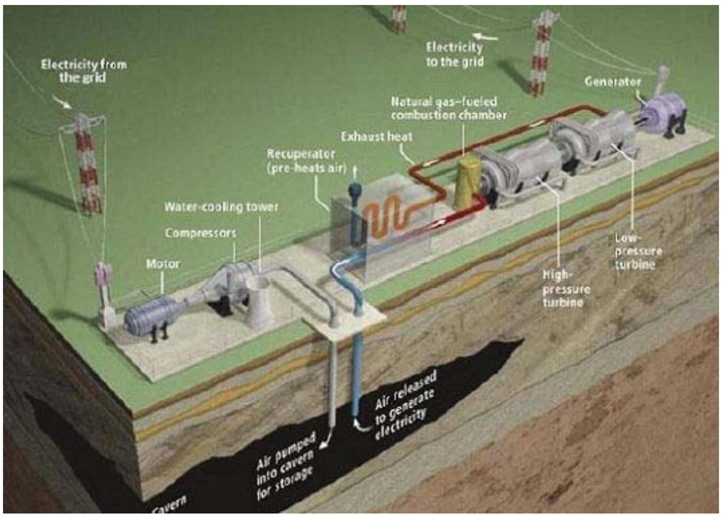


Fig. 2-31 Compressed air storage

2.5.2 Chemical Storage

2.5.2.1 Lead Acid Battery

In lead acid battery, the active material of positive and negative electrode is PbO2 and sponge metal lead separately, and the electrolyte is sulfuric acid solution.

2.5.2.2 Sodium Sulfur Battery

Sodium sulfur battery is a new type battery, which adopts molten liquid electrode and solid electrolyte. The active material of negative plate is molten metal sodium and the active material in positive electrode is molten sulfur and Sodium polysulfide.

2.5.2.3 Flow Battery

Flow battery, is a battery which positive and negative active material is a liquid couple. At present the mainstream of flow batteries is all-vanadium flow battery, with iron-chrome being halted and Sodium polysulfide / bromide battery being rising initially.

2.5.2.4 Sodium/Nickel Chloride Battery

Sodium/nickel chloride battery is new type storage battery, which is developed on the base of Sodium sulfur battery. It has higher energy density and power density, and other advantages including over charge endurance, low self-discharge rate, easy operation maintenance, etc.

2.5.2.5 Lithium Ion Battery

The positive and negative electrodes of lithium ion battery adopt active materials in which lithium ion can intercalate and de-intercalate freely, charge and discharge by the moving of lithium ion between positive and negative plates. The materials containing lithium element is generally adopted in positive electrode and materials like graphite is adopted in negative electrode. The electrolyte contains organic solvent and lithium salt solute. The advantages of lithium ion battery include high energy density, high efficiency and long cycle life.

2.5.2.6 Lead Carbon Battery

Lead carbon battery is one of the most advanced lead acid battery, integrating the capacity advantage of lead acid battery and the power advantage of ultracapacitor, which has the following technical advantages.

- Ultra long cycle life, more than 4200 cycles at 70% DOD, 15-year design life; more than 3500 cycles at 70% DOD even in series connection.
- Superior charge acceptance, lead carbon technology being adopted to increase charge acceptance, reduce the sulfation of negative plate, more suitable in partial state of charge (PSOC) environment, especially in energy storage of renewables.

Tab. 2-4 Technical parameters of Typical FCP lead carbon battery

<table>
<tr><th colspan="2">Model</th><th>FCP-500</th><th>FCP-1000</th></tr>
<tr><td colspan="2">Nominal voltage of cell</td><td>2V</td><td>2V</td></tr>
<tr><td colspan="2">Depth of charge 70%</td><td>4200 cycles</td><td>4200 cycles</td></tr>
<tr><td colspan="2">Depth of charge 45%</td><td>6000 cycles</td><td>6000 cycles</td></tr>
<tr><td colspan="2">0.1C10A(1.8V/cell)</td><td>500Ah</td><td>1000Ah</td></tr>
<tr><td colspan="2">Discharge at 0.16C10A(1.8V/cell)</td><td>425Ah</td><td>850Ah</td></tr>
<tr><td colspan="2">Discharge at 0.23C10A(1.8V/cell)</td><td>375Ah</td><td>750Ah</td></tr>
<tr><td colspan="2">Voltage control</td><td>1.8V-2.35V/cell</td><td>1.8V-2.35V/cell</td></tr>
<tr><td colspan="2">Equalizing charge conditions</td><td>2.45V/cell</td><td>2.45V/cell</td></tr>
<tr><td colspan="2">Temperature recommended</td><td>5-35℃</td><td>5-35℃</td></tr>
<tr><td rowspan="2">Maximum current for constant operating</td><td>charge</td><td>0.2 C10 A</td><td>0.2 C10 A</td></tr>
<tr><td>discharge</td><td>0.4 C10 A</td><td>0.4 C10 A</td></tr>
</table>

Model		FCP-500	FCP-1000
Temperature	charging	0-40℃	0-40℃
	discharging	−15–45℃	−15–45℃
	Storage	−15–45℃	−15–45℃
Dimensions (Length*Width*Height) mm		166*172*508	303*172*508
Weight (kg)		41	75

(Source: Shandong Sacred-sun Power corp. Ltd.)

In June, 2014, one of the advanced lead carbon battery manufacturers in APEC areas, Shandong sacred-sun Power corp. Ltd. began mass production of FCP products which are large-capacity, deep-cycle and ultra long life. The FCP product is being applied to the increasingly fast developing renewable energy market.

Fig. 2-32 FCP lead carbon battery

2.5.3 Electromagnetic Storage

2.5.3.1 Super Conducting Magnetic Storage

Super conducting magnetic storage (SEMS) unit is consisted by super conducting wires in a deep low temperature produced by refrigeration equipment containing liquid nitrogen. Power converting /conditioning system connects the SMES unit with AC power system, and charge or discharge the storage wires according to the need of power system. Two kinds of power converting system are generally used in connecting storage wires and AC power system, one is current supply type, the other is voltage supply type.

2.5.3.2 Super-capacitor Storage

Super-capacitor is a new type of storage unit between conventional capacitor and chemical battery. The super-capacitor has both high power discharge capacity like conventional capacitors and electricity storage capacity like chemical battery. Compared to conventional capacitor, super-capacitor has ultra large capacity in F class, higher energy density, wider operating temperature range and longer life, and the cycle number can reach more than ten thousand without maintenance. Compared to chemical battery, super-capacitor has higher specific power and be no pollute to environment.

2.5.4 Comparison of Energy Storage Technology

Tab. 2-5 Comparison of different kinds of energy storage technology

Energy storage technology	Advantage	Drawback	Application
Pumped storage	Reliable, large capacity and long life.	Special geographical requirement, low energy density, long period of construction, large investment.	Peak shifting, frequency and phase regulation, system backup, black-start.
Flywheel storage	High power density, long life.	Low energy density, high self-discharge rate, high cost.	Peak shifting, frequency regulation, UPS, electricity quality control.
Compressed air storage	Large capacity, low cost.	Special geographical requirement.	Peak shifting, frequency and phase regulation, system backup power, black-start.
Lead acid battery	Matured technology, low investment, short period of construction.	Short life, Environment protection.	Electricity quality and reliability control, frequency regulation, black-start.
Lead carbon battery	Long life, short period of	The cost need to fall further.	Many applications.

Energy storage technology	Advantage	Drawback	Application
	construction.		
Lithium-ion battery	High energy density, high efficiency	Poor uniformity when connected in series, high cost.	Many applications.
NAS battery	High energy density, high efficiency	High cost, safety issues.	Many applications.
Redox flow battery	Large capacity	Low energy density, low efficiency.	Electricity quality and reliability, frequency regulation, peak shifting, energy management
Sodium/Nickel chloride battery	High energy density, high efficiency.	High cost	Many applications.
Super conducting magnetic storage	High energy density, high efficiency.	High cost	UPS, electricity quality control, stability of transmission and distribution system.
Super-capacitor	Long life, high efficiency.	Low energy density.	Electricity quality control, stability of transmission and distribution system, pulse power output.

2.6 LCMT Energy Consumption and Recycling

Currently in LCMT, low-carbon is generally realized via energy-saving, new energy utilization and other forms, whereas increased recycling and utilization of secondhand energy is becoming one of the most important means in enhancing energy utilization efficiency, such as blast furnace top over-bottom pressure and waste heat recycling power generation, Cowper stove flue gas and waste heat recycling power generation, garbage collection power generation, and elevator mechanical energy recovery, etc.

Energy feedback device is a common technology that use power electronics converter technology to convert mechanical energy (potential energy, kinetic energy) produced during motion of elevator and other equipment to electric energy (renewable energy), which will be fed back to the grid for the equipment itself or other electric equipment. The device reduced unit time power grid consumption of electrical machinery towage system, thus achieving the goal of energy conservation. Energy feedback device has become a key technology in developing energy-saving and environmentally friendly medium or high-speed elevator, marking that elevator product has reached international advanced level. With popularization and application of these technologies, more solutions will be reached for energy recycling of APEC LCMT.

3 Energy Management System

Energy management involves whole process of production, transmission, distribution, exchange and utilization of multiple energy resources including electricity, water, heat, fuel gas, and several functions including energy consumption management of various users, distributed new energy system power generation management, energy storage devices charge and discharge management, system energy conservation management, intelligent allocation and exchange of different energy resources, energy system analysis and load regulation, equipment life cycle management, and secure access of new energy, etc. This report mainly emphasize on analyzing electricity management system of low-carbon towns.

3.1 Overview of EMS

EMS is an integrated automatic system of modern electric system supported by computer technology and electric system application software technology, as well as the integration of energy system and information system. Management mentioned here refers to comprehensive management of different automatic systems, which replace analog computation technology with digital computer technology to realize most functions with software rather than hardware.

EMS has following important issues: safe and efficient access and utilization of distributed renewable energy, equipment utilization strategy under flexible price mechanism, comprehensive management and system energy conservation of multiple user side energy, safe charging of electric mobile, intelligent, personalized and convenient user end energy utilization, and bilateral interaction of energy supplier and demander. Overall requirements for energy management at user side are green and low-carbon, economic and energy-saving, safe and efficient, interactive and friendly, so that users' demands for energy can be all satisfied, interactive integration and efficient, comprehensive and economic utilization of different energy resources can be realized and energy consumption together with energy utilization cost can be reduced with higher energy utilization efficiency.

3.2 EMS Constitution

EMS constitution: computer and / or server, Ethernet or communication network connected by Local Area Network (LAN), wireless transmission part, wire transmission part and energy management software, each measuring point (flow meter, content gauge, temperature, pressure, etc.), electricity meter and other parts.

Hardware constitution: meters of each collecting point (flow meter with RS458 communication, electricity meter, etc.), integration box of collected or transferred data, working wired network, upper computer main engine.

Software constitution: communication agreement of meters, access program for collecting wired network data; meter reading software for collecting wireless network, suitable data base, energy management software that analyzes and displays data.

Interface display: data accumulation value and real time inquiry value of each point, energy consumption value by calculation, flexible operation backstage that can import and export, select and store information and allows post-maintenance and extension, energy report made according to the collecting and control point demanded by users, operation interface that supports network sharing through user side visit and allows administrator to visit and maintain.

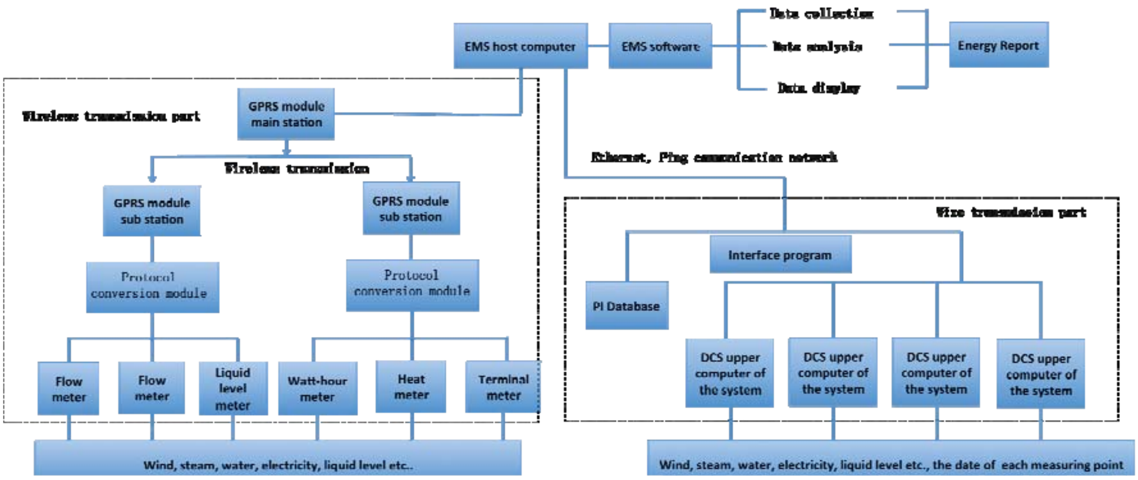


Fig. 3-1 Typical EMS structure

3.3 EMS Functions

The functions of EMS are:

- Monitoring device energy consumption to improve overall management level;
- Finding out low efficient devices;
- Looking out energy consumption faults;
- Reducing peak load power consumption;
- Realizing centralized control, operation, adjustment and parametric setting of the main device;
- Realizing faults, malfunction and accident treatment;
- Achieving real time and short time filing, database filing and real time inquiry of energy operation power flow data;
- Realizing comprehensive balance, reasonable allocation and optimal dispatching of energy system via energy consumption data analysis.

3.4 EMS Division

From the perspective of application area, EMS can be divided into building EMS, Industry EMS, public utilities EMS (municipal administration), household EMS, as well as other subdivide sectors including military, scientific research, shipping, and transportation, etc.

Seen from constitution parts, EMS is made up of power supply system, water supply system, gas supply system, cold supply system, and heat supply system, etc.

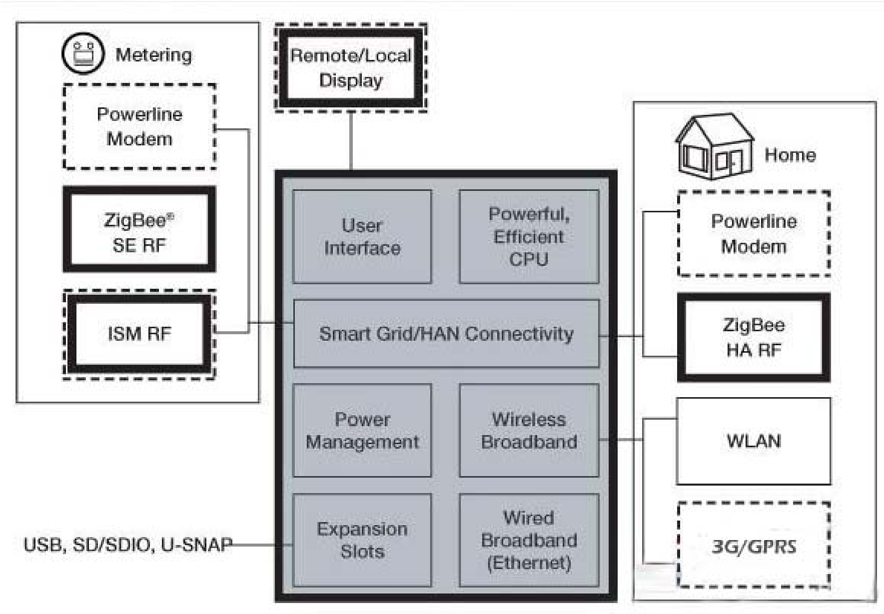


Fig. 3-2 Household EMS

(Source: Huaqiang electronic network)

3.5 EMS Application and Development Trend

Invented in middle 1970s, EMS integrates AGC (Automatic Generation Control) and some network analysis functions to realize all functions via digital computer system on the basis of data collecting and SCADA (Supervisory Control and Data Acquisition).

The computer hardware system of EMS developed from adopting exclusive controlling computer initially to utilizing general-purpose computers for all; while the computer software developed from specially designed control program to adoption of general-purpose control system, exclusive database and picture compiling system as well as dedicated EMS supporting platform. With development of electric system model and algorithm, advanced application software of EMS will be gradually improved and enriched, thus providing innovated and upgraded EMS functions.

New generation EMS has the following characteristics:

(1) Network –Internet Technology is applied in EMS in these ways: client/ server model will be replaced by browser service system structure; remote control and operation as well as comprehensive information database visiting will be realized via network; information and data exchange capacity between systems will be increased and seamless connection of data

information with network will be achieved through firewall; premise distribution system in buildings will be directly used; remote fault diagnosis and recognition will be realized for energy system operation status inquired by remote computer, phone and mobile phone.

(2) Openness and interoperability of system – standard network communication protocol is normally open and able to connect various devices made by different manufactures.

(3) optimal control – EMS can diagnose, recognize, forecast and optimize energy consumption at the system level with key technologies of different forecasting and optimization algorithm.

3.6 Application Area of EMS

EMS is widely used in low-carbon towns in different areas, including renewable energy, intelligent building, and smart home, etc. Practical application cases of different areas will be introduced in the following.

3.6.1 Renewable Energy

3.6.1.1 The Demonstration and Research Center of Smart Micro-grid in Shanghai

Fig. 3-3 Demonstration and research center of smart micro-grid in Shanghai

The construction project of the Demonstration and Research Center of Smart Micro-grid in Shanghai University of Electricity is one of the key construction projects. It is located in Shanghai University of Electricity, Yang Pu North Campus (Changyang Road No. 2588). This project will make full use of campus roof and open field to install a certain amount of photovoltaic and wind power generation system, and connect to the micro gas turbine, energy storage device, electric vehicle charging station, and simulated diesel generator system. Accompanied with the grid, the system will supply power to campus load together with the power grid. This project plans to construct 222.75 kW photovoltaic power, 10 kW wind power, 55 kW micro gas turbine power, and 50 kW simulated diesel power, and the load power is 208 kW, the energy storage system power 300 kW. Besides, the intelligent power system will be built in graduate student dormitory in order to achieve intelligent power utilization bidirectional interaction. Meanwhile, the 100KW/500KWh lead-carbon battery energy storage system, provided by Shandong Sacred Sun Power Sources Co. ltd, is an important part of the whole micro-grid project.

In addition, the lead-carbon batteries have been widely used in grid energy storage, new energy access peak load shifting, showing a good example effect and application potential.

Fig. 3-4 Smart grid energy storage system in New Mexico, USA

Fig. 3-5 Load stabilization and peak load shifting energy storage system

3.6.1.2 7.02 MW Photovoltaic Energy Storage Power Station

This Photovoltaic Energy Storage Power Station in CGNPC is a kind of photovoltaic-battery power station with micro-grid architecture, which includes 7023 kWp photovoltaic, 20.7 MWh lead-acid battery and 5MWh lithium iron phosphate batteries. The photovoltaic inverter devices, energy storage system will be installed in the form of container.

This project adopts the new complementary mode of distributed photovoltaic and battery， ensuring smooth photovoltaic power supply. It uses complementary lithium battery energy storage system to reduce the charging frequency of lead-acid storage battery, which prolongs the life of the lead-acid battery and improved the system performance. At the same time, the sharing way of micro-grid will make full use of photovoltaic power generation, and it can avoid ‘power abandoning’ and ‘power failure’ phenomenon in the independent photovoltaic system. The construction of this project shows a good template for achieving generate-and-consume, local consumption and high efficiency in the off-grid area in APEC.

The use of container-form lead-acid battery equipment enables the one-stop energy storage system design. The lead-acid battery and battery management system (BMS), communication monitoring, thermal management system and other equipment are organically integrated into a standard unit. This standard unit has its own off-grid system, temperature control system, heat insulation system, flame retardant system, fire alarm system, electric interlocking systems, mechanical interlocking system, safety evacuation system, emergency system, fire-fighting system, automatic control and security system. With IP54 protection class, it can operate under an unmanned condition. It can operate efficiently and stably for a long time at high altitude, strong wind, extreme temperatures and other harsh environments.

The design and production, delivery, Ex work, field installation Shandong Sacred Sun Power Sources Co. ltd provided the 20 MWH container form lead-acid battery equipment for the project, design of the whole production, equipment testing and training, trial operating and after-sales service of the 20MWh container-form lead-acid battery were provided by Shandong Sacred Sun Power Sources Co. ltd. The 32 sets of containers form lead-acid batteries, with a capacity of 20MWh, have been put into trial operation at the beginning of 2014.

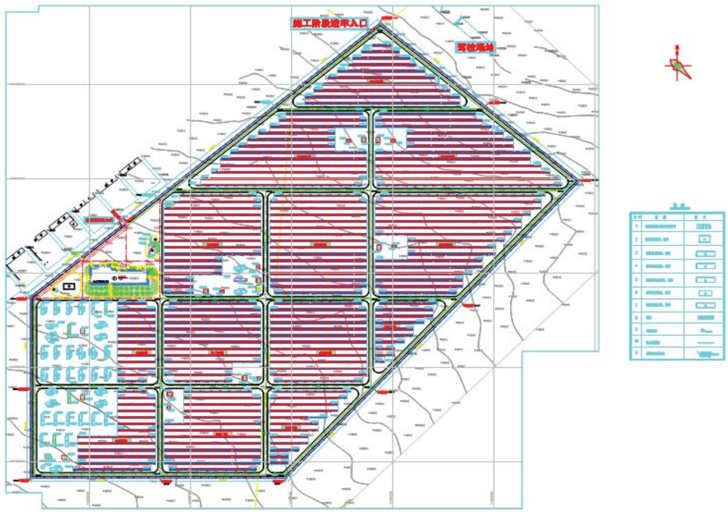


Fig. 3-6 Project layout diagram

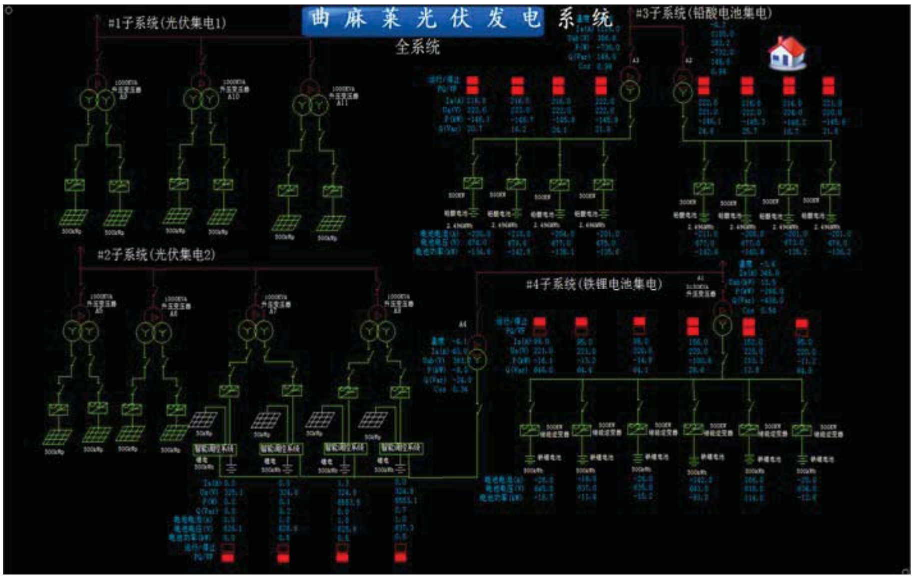


Fig. 3-7 System topological diagram

Fig. 3-8 Photovoltaic Energy Storage Power Station in CGNPC

Fig. 3-9 Photovoltaic Energy Storage Power Station Structure

3.6.1.3 1.274MW Photovoltaic-battery-diesel Micro-grid Power Station

This project belongs to the off-grid photovoltaic-battery-diesel micro-grid power stations, which includes 1274KWp photovoltaic system on the principal island, 5.8MWh lead-acid batteries and 0.8MWh lithium iron phosphate batteries. The photovoltaic-inverter devices and the energy-storage systems are installed in container form. This station, built by Shandong Sacred Sun Power Sources Co. ltd, is also the first megawatt independent micro-grid power station.

The micro-grid energy-storage project started in June 2013 on the Beiji Island includes 1274KWp photovoltaic system, 0.5MW/0.8MWh lithium iron phosphate battery energy storage system, 1MW/5.8MWh lead-acid battery energy storage system, micro-grid operation control system, energy management system, micro-grid protection system and the security-and-stability system. Some original technologies, such as double-end multiple distributed generation subsystems technology, mixed battery management technology, seamless connection technology for the cooling devices of diesel groups, were introduced into the project to realize the supply-and-storage and mixed battery storage, which greatly improves the life and efficiency of batteries and the investment benefit.

A new complementary mode between the distributed photovoltaic power and mixed batteries were used in the project. The lead-acid batteries is used to stabilize the power supply, and the Li-ion battery was used to reduce the charge and discharge times of the lead-acid batteries to extend their lives, thus improving the cost performance of the system. At the same time, the micro-grid-sharing mode can maximizes the use of photovoltaic power, avoiding the power abandoning and power failure. The project will dramatically reduce the diesel power and provide a template for the off-grid photovoltaic power on islands to realize the mode of generate-and-consume, local consumption and high efficiency. The project has passed the acceptance and performed trial operation in June 2014.

Fig. 3-10 1.274MW Photovoltaic-battery-diesel Micro-grid Power Station

Fig. 3-11 1.274MW Micro-grid Power Station energy storage system

3.6.1.4 Zhangbei Wind-solar Storage and Transmission Pilot Project

Taking advantage of natural complementation of wind and solar energy in time and space of Zhangbei area in North China, together with application of large capacity chemical energy storage system, the project established combined power generation forms with three systems including wind generation, photovoltaic generation and energy storage devices of five configurations. Through power prediction, combined power generation and smart monitoring control, the project aims to effectively improve generation properties of wind power and solar photovoltaic, stimulate renewable energy as wind power and solar energy to reach or approach the performance of conventional power supply, realize harmonious development of renewable energy and power grid and other power supply, solve the technical bottleneck of large-scale grid-connected operation of renewable energy, and promote intelligent construction of large-scale renewable energy reception and dispatch control by the power grid.

Fig. 3-12 China National Wind-solar Energy Storage Demonstration Project

The project developed smart panorama control system of combined generation to carry out unified coordination of the whole wind-solar storage and transmission system, thus realizing AGC and AVC functions that make, order and execute generation plan automatically and becoming a pivot with friendly network source that coordinate power generation. Besides, a large-scale lithium battery power station is built with nine energy storage units composed of 1,402 battery cupboards and 274,568 battery cells.

Fig. 3-13 China National Wind-solar Storage and Transmission Demonstration Project

3.6.2 Intelligent Building

3.6.2.1 US GSA Intelligent Building Strategy

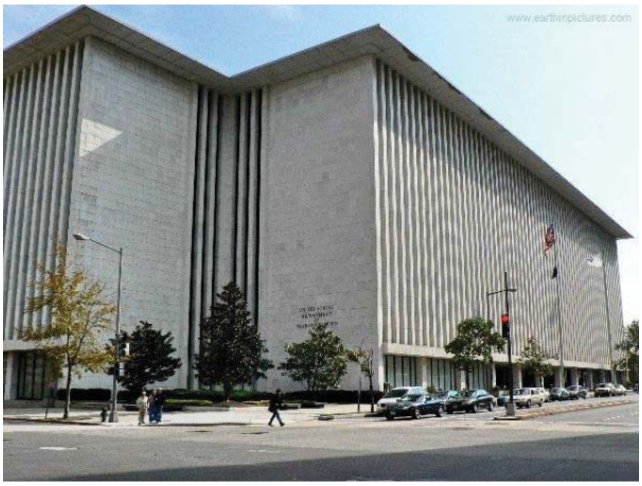


Fig. 3-14 US federal building

The 182-million-square-foot National Multi-function Office center owned by General Services Administration is one of the key intelligent building projects advocated by the U.S. government. American Recovery and Reinvestment Act awarded $4.5 billion to GSA and cooperated with IBM to jointly develop and install advanced intelligent building technologies in 50 most energy-consuming federal government buildings. As the greatest project of GSA intelligent building strategy, the project will connect building management system to central cloud computing platform to increase efficiency with 30% energy conserved and as high as $15 million per year saved for the taxpayers.

Thanks to efforts from different sectors of the society, National Federal Building is harvesting energy saving fruits gradually. The U.S. government specially authorizes Pacific Northwest National Laboratory of DOE to carry out evaluations on 22 green federal building throughout the whole country. Statistics show that 34% carbon dioxide emissions, 11% water consumption as well as 19% post maintenance fees are reduced contributed to these green buildings.

3.6.2.2 IBM Intelligent Building

As early as 2008, IBM put forward the expectation of intelligent earth and intelligent city, aiming to confront energy, social service, environment protection and other big challenges with new technologies that are sensitive, interacting and intelligent. As a part of intelligent earth, intelligent city can be built with intelligent medical treatment, intelligent transportation, intelligent education, intelligent energy resources, intelligent transmission, and intelligent communication, etc. the theory of IBM is brought up and practiced in three steps.

Fig. 3-15 IBM intelligent building

Firstly, IBM has accomplished more than 2,000 intelligent city programs globally in the past decades, among which are Dubuque intelligent water meter management, social water resource management, leak detection, Singapore intelligent transportation management, Dublin intelligent city management, Amsterdam intelligent airport, Taipei intelligent trains, and Stockholm intelligent transportation, etc.

Secondly, based on all these intelligent city programs, IBM came up with a unified mode to build intelligent city, which can be summarized as information utilization, problems analysis, and resources coordination as presented by the following picture.

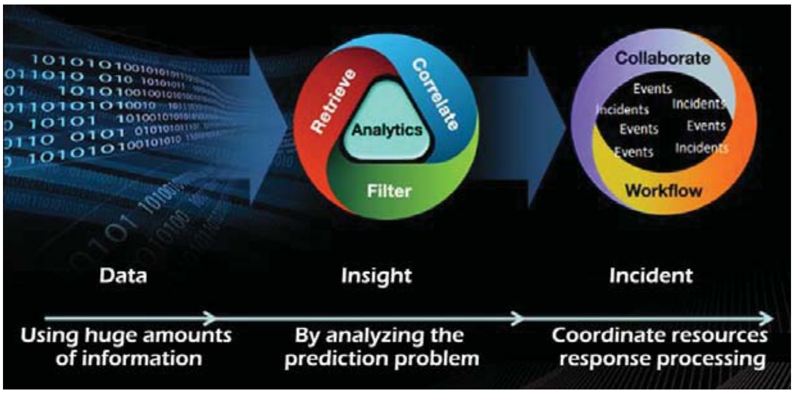


Fig. 3-16 Unified mode of intelligent city building

(Source: The fourteenth of Wall Street financial observation phase: Future Energy Internet development trend of real-time large data)

Thirdly, IBM constructed intelligent city solution with its technologies. The following picture shows framework of IBM intelligent city solution. The undermost part is information sensation part, in which information of different sources is accepted via definition of data format to be integrated into intelligent city operation center platform; the middle part is the core framework of intelligent city building, which provides service direction, analyzes modeling capabilities, work flow, key performance indicators definition ability, and reporting abilities, and presents a visual management interface; the upmost part are solutions for different industries constructed on this platform to serve different operating departments. The intelligent industry solution assets repository lies in the upper right is intelligent city cooperation partner eco system established by IBM. All intelligent industry solutions based on IBM platform can be submitted to the assets repository, so that applications of cooperative partners can be visited by global users after examination and verification.

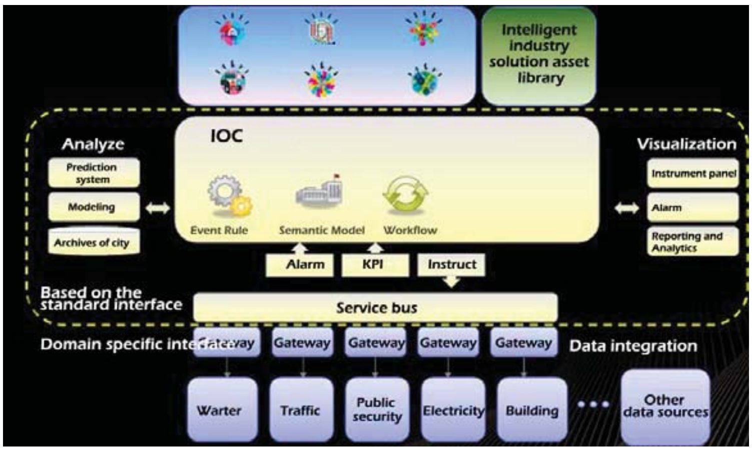


Fig. 3-17 Intelligent city solution frameworks

(Source: The fourteenth of Wall Street financial observation phase: Future Energy Internet development trend of real-time large data)

The same theory has been applied to similar buildings in the UK, such as the conception house designed by Professor Phil Jones from Cardiff University Wales School of Architecture for Wales Guevara Housing Council is based on three major factors to realize sustainable building design: firstly, to approach 'zero-carbon' emission as closely as possibly; secondly, to reform in construction mode and material utilization; thirdly, to employ replaceable and renewable energy resources.

Two aspects relating sustainable construction material are reuse and recycle. Site operation should be replaced with modern construction method as factory prefabrication as more as possible. Basically, solar radiation is the only source for winter heating, which can be achieved with passive solar houses equipped with solar thermal collector for hot water heating together with indoor heat dissipation of body and equipment.

Ventilation devices with 'heat restoring' performance will be used for ventilation system to heat new wind via the temperature difference between exhausted air and fresh air in winter. Main living space is designed to the south, with southern double glass curtain wall being used in winter to heat fresh air supply and then exhausted mechanically from northern service space. Besides, solar photovoltaic panels and solar thermal collectors are installed on roof top.

Since the UK requires a longer heating period which consumes large amount energy resources as a result but have no need for air conditioning system due to cool summer climate, solving the problem of passive heat supply will save conventional energy and reduce carbon dioxide emission significantly.

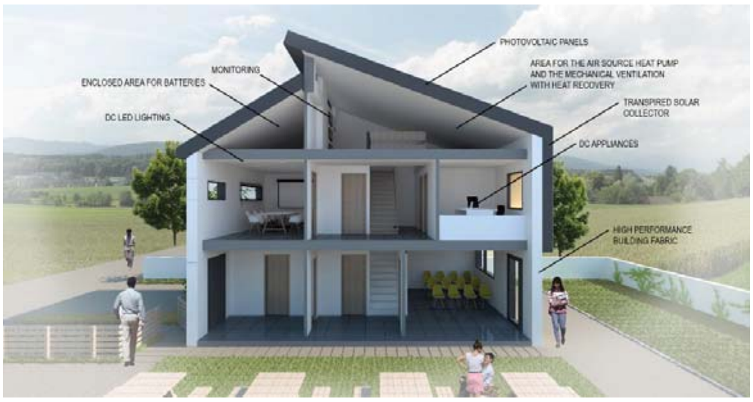


Fig. 3-18 Building energy management system (BEMS)

3.6.3 Smart House Sector

3.6.3.1 OPOWER

Opower, which focuses on household energy conservation, is founded in the US in 2007. It has developed an information interaction platform integrating behavioral science, data analysis as well as cloud technology, thus winning trust of customers by saving more energy for global families.

With the 'Electric Industry Customer Interaction Platform' developed by Opower, users can have easy access to monthly electricity bills and compare with other families in relation to electricity consumption, while electricity suppliers can send users some information and energy-saving tips visa user side or email. During electricity consuming peak season, users can choose to reduce energy consumption once they get information feedback from suppliers to exchange for credit limit. In this way, users can not only save electric charge but also earn electricity charge thanks to this platform.

Fig. 3-19 Household EMS

3.6.3.2 Nest Labs Smart Housing

The first product promoted by Nest Labs is intelligent temperature controller. It can automatically set temperature according to the analysis by Nest labs server on data recorded and uploaded by itself, thus maintaining a comfortable indoor temperature. Moreover, it can regulate indoor temperature to save energy when the room is empty.

When intelligent controller became comparatively mature after several times product upgrading, Nest labs released its second product – intelligent smoke detector, which possess six sensors sensing smoke, carbon monoxide, temperature, light, motion and ultrasonic wave. When smoke is detected, it will remind users with sound or light. Moreover, it can provide remote alarming, which can be turned off with gestures.

In addition, these two products of Nest Labs can communicate with each other to better serve for home life, such as judging indoor conditions via temperature and smoke indicators.

Nest developer plans to open Nest software platform towards all third party application developer and realize interconnection and interworking of Nest current products and other smart home devices including smart watch and washing machine, etc. Besides, Nest smart home platform will combine a series of different smart household electric appliances harmoniously with a unified standard.

Nest opened Nest API for developers so that they can utilize Nest hardware and algorithm to integrate other smart home appliances with Nest products, thus realizing smart control of different products including air conditioner, refrigerator, desk lamp and fan lamp, etc.

Fig. 3-20 Intelligent thermostats

Fig. 3-21 Nest products

3.6.3.3 LG Smart Home System

LG smart home system Home Chat employed natural language treatment technology to realize communication between intelligent household electric appliances and users through Internet or mobile communication devices. All household electric appliances produced by LG will be equipped with digital update and smarter brains gradually so that remote control can be carried out via simple text orders.

Fig. 3-22 LG smart home system

3.6.4 Others

Fig. 3-23 Tesla electric mobile

One of Tesla’s core technologies lies in BMS. Panasonic combined NCA series 18650 lithium batteries energy package works as Tesla’s power source, and about 8,000 Panasonic 18650 batteries will be used for each Tesla Model S. The reason that Tesla strictly sticks to using small-capacity Panasonic 18650 batteries instead of large-capacity battery units is because of low-cost but secure features of this battery. Moreover, once thermo-runaway problems appear, surrounding battery units is not likely to be affected due to its small capacity.

Tesla designed decentralized management of these batteries with 69 battery units forming a battery pack by parallel connection and 9 battery packs making up a battery cube by series connection until the whole battery panel come into being by parallel connection of battery cubes. With fuses in each battery unit, battery pack and battery cube as well as electric current, voltage and temperature monitoring at each level, the fuse will be blown with excessive current

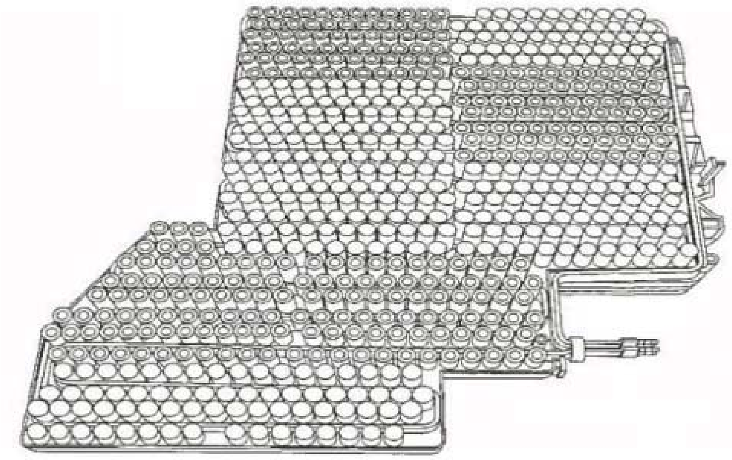


Fig. 3-24 Tesla battery pack structure

With the whole battery package arranged to base plate of the electric mobile, risk of short-circuit triggered by collision is reduced, thus guaranteeing a safer use of electric mobile under extreme crash.

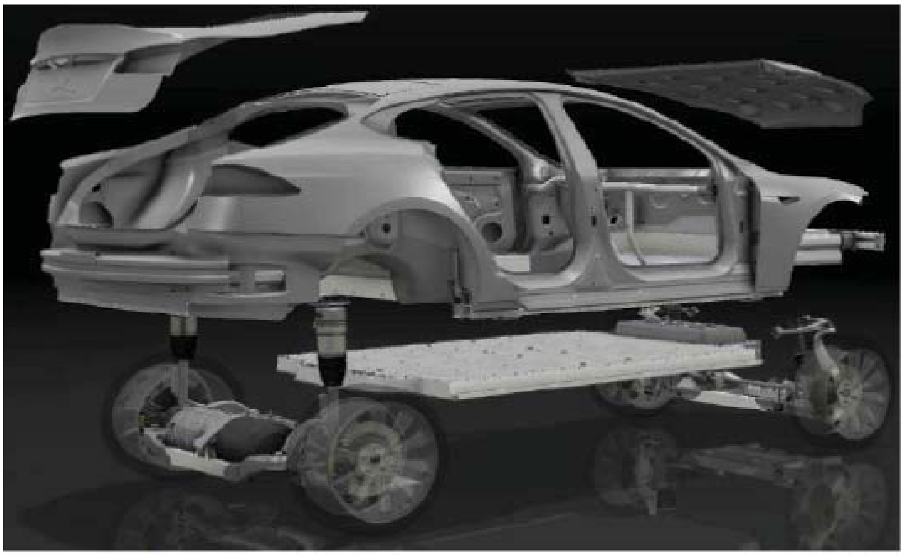


Fig. 3-25 Battery package installation

As the core technology of Tesla electric mobile, BMS enjoys the following advantages:

- Monitoring condition of each battery to carry out in-time intervention and isolation;
- Two dimensionality determining the battery safety of electric mobile are safety performance of battery cell and reliability level of power management system;
- Technological development branch of battery cells shows that small-size battery cell route used by Tesla requires higher complexity for power management system;
- Though safety of single 18650 battery is controllable, several parallel-connected batteries is highly exposed to temperature, voltage and unbalanced electric current problems among them, which is harmful to the stability, security and life span of the battery pack. With the temperature control system, cooling system, charge balance system developed independently by Tesla, single battery faults can be effectively monitored and repaired so that stability and safety of the whole battery can be ensured.
- Battery package temperature examination system is also called smart temperature monitoring. Each battery cell of Tesla mobile battery package is connected to one thermistor, which is integrated to battery examining device and a series of light-guide fiber that is connected with photosensitive inductor.

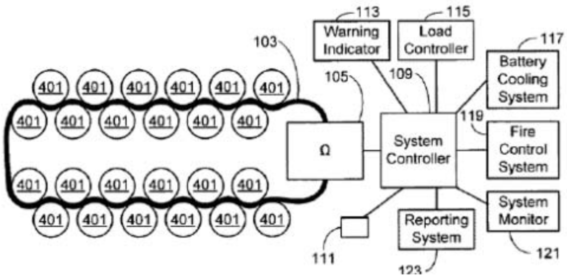


Fig. 3-26 Smart temperature monitoring

- Battery package liquid condensing system is also called real-time temperature control. The engine liquid condensing system researched and developed by Tesla is double-mode condensing system. The first layer cooling circuit is dedicated to battery package cooling; while the second layer, including the second cooling fluid reservoir and exchanging heat with at least one rotatable part, is parallel to the first layer cooling circuit, thus guaranteeing an independent battery package cooling system.

3.7 EMS Evaluation Model

3.7.1 EMS Evaluation Model

According to energy production, transmission, utilization and other processes, the EMS evaluation model can be divided into 6 modules and 15 evaluation fields as following:

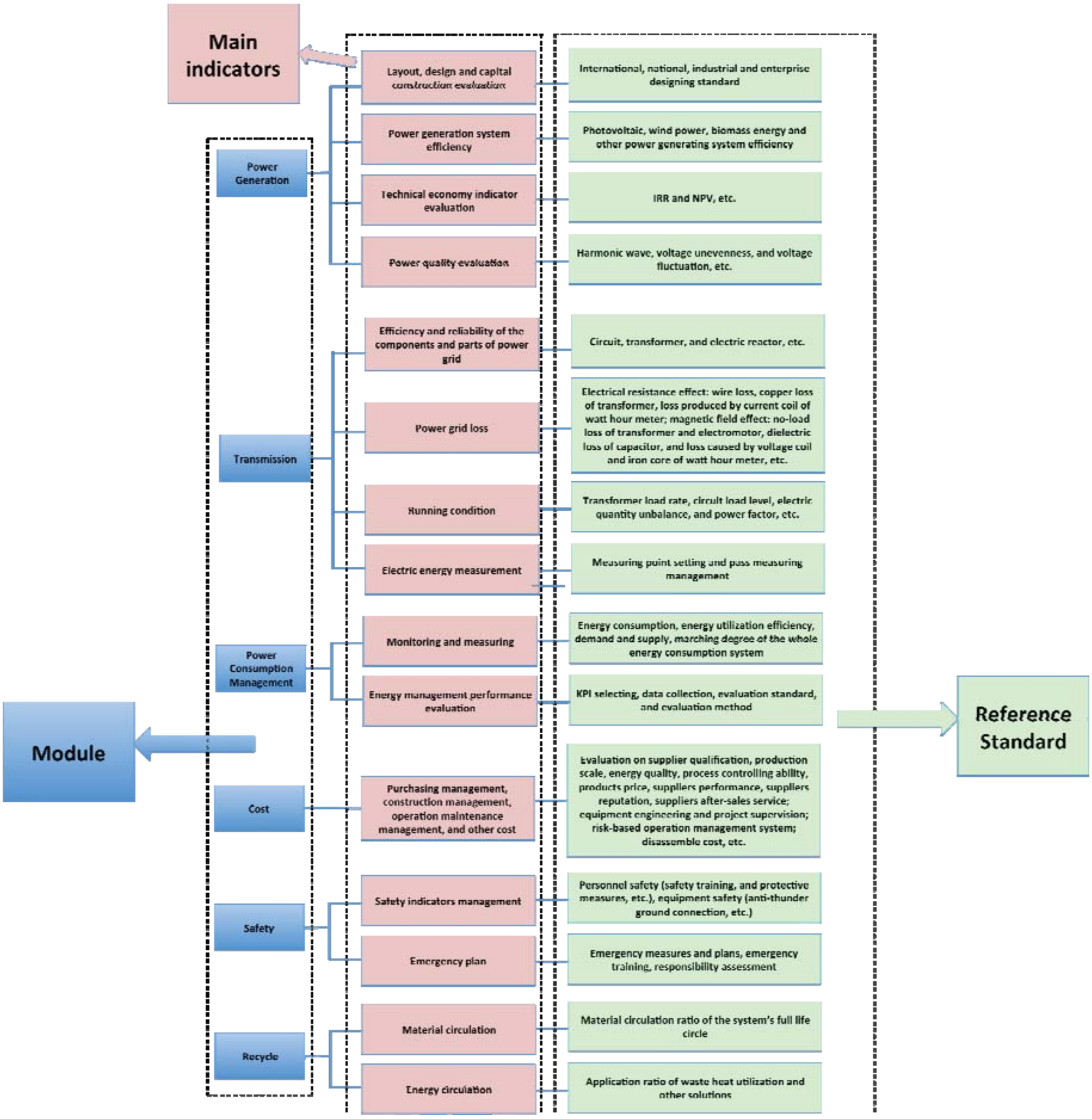


Fig. 3-27 EMS evaluation model structure

There are 6 modules in the EMS evaluation model:

- Power generation

- Transmission
- Power Consumption Management
- Cost
- Safety
- Recycle

There are specific indicators or key performance index (KPI) in each module as specified above, and standards or methods to calculate or evaluate each sector's performance.

3.7.2 China New Energy City Evaluation System

China is now actively promoting LCMT and new energy demonstration cities project, the indicator system of which can be referred to by other APEC economies.

China new energy demonstration cities refer to cities where consumption of renewable energy including solar energy, wind power, geothermal energy and biomass energy reaches a higher level or comparatively large scale during the process of urban energy development. The following renewable energy resources and technologies are to be promoted significantly:

- Solar energy heat utilization
- Distributed solar energy photovoltaic power generation system
- Distributed wind power generation
- Biomass clean fuel utilization
- Municipal solid waste utilization
- Geothermal energy, surface water and air energy utilization
- New energy transmission

In order to carry out quantitative evaluation, China has made a series of new energy city evaluation system, of which new energy utilization proportion, the proportion of declared new energy utilization amount by the end of the project to overall municipal energy consumption, covers production and application of various new energy, thus representing the general level of the city's new energy promotion and application. Specific indicator system is as follows:

Tab. 3-1 China new energy city evaluation system

First-class indicator	No	Second-class indicator	Main evaluation requirements	Remarks
New energy utilization indicator	1	New energy utilization to overall energy consumption ration	≥6%	
Classified new energy utilization indicator	2	Solar power utilization (optional)		Applicant city is supposed to choose at least two second-class indicators according to its own resources condition
	2.1	Solar energy heat utilization	Accumulated solar thermal collection surface ≥1 million m^2, or per capita solar thermal collection surface ≥360 m^2/per thousand people	
	2.2	Distributed solar photovoltaic installed capacity	Accumulated installed capacity ≥ 20 thousand Kilowatt	
	3	Distributed wind power generation installed capacity	Accumulated installed capacity ≥ 10 thousand Kilowatt	
	4	Biomass energy utilization		
	4.1	Biomass energy utilized amount	Utilized total ≥ 100 thousand tce per year	
	4.2	Utilization of marsh gas and sludge from municipal waste water treatment plant	Scientific and reasonable marsh gas and sludge utilization plan	
	5	Geothermal energy utilization	Total area of building that employs large-scale Geothermal energy heat supply and heat pump heat supply (refrigeration) ≥3 million m^2.	
	6	Other new energy utilization	Utilized total of other new energy ≥ 50 thousand per year	

(Source: NEA, China)

3.7.2.1 New energy utilization proportion

New energy utilization proportion of low-carbon towns refers to the proportion of declared new energy utilization by the end of the planning period to overall municipal energy consumption. This indicator, which covers the production and application of various new energy resources, can represent the general level of the city's new energy promotion and application. The computational formula is as follows:

$$\text{Municipal new energy consumption proportion} = \frac{\text{new energy consumption by the end of the planning period}}{\text{energy consumption by the end of the planning period}}$$

New energy utilization proportion by the end of planning period required by the evaluation indicator is no less than 6%.

3.7.2.2 Solar Energy Heat Utilization

This indicator aims at representing popularization degree and utilization scale of solar energy utilization.

According to the indicators, solar energy heat collection surface should be no less than 100 thousand square meters or per capita solar energy heat collection surface be no less than 360 square meters per thousand people.

$$\text{Per capita solar energy heat collection surface} = \frac{\text{Installed surface of urban solar energy heat collector by the end of planning period (square meter)}}{\text{Urban population by the end of planning period (thousand people)}}$$

3.7.2.3 Installed Capacity of Distributed Solar Photovoltaic

Distributed solar photovoltaic generation system refers to photovoltaic power generation equipment operated with grid users integrating into the power grid. Its construction can be connected with smart grid and micro grid technologies.

In line with this indicator, the installed capacity of solar photovoltaic generation at user side by the end of planning period should be no less than 2 thousand Kilowatt.

3.7.2.4 Installed Capacity of Distributed Wind Power Generation

Distributed wind power generation is connected to secondary distribution network, generating power for local users or the power distribution network. The indicator requires more than 10 thousand Kilowatt installed capacity for distributed wind power by the end of planning period.

3.7.2.5 Biomass Energy Utilization

(1) Biomass energy utilization amount

This indicator, showing the utilization of biomass briquette in cities and towns as well as the quantity of fossil energy replaced by power generated by direct-fired biomass, requires biomass energy consumption of no less than 10 thousand tons standard coal per year.

(2) Utilization of marsh gas and sludge produced in municipal sewage treatment plant

This indicator encourages utilization of marsh gas and sludge produced in municipal sewage treatment plant, which is of great importance in promoting popularization and application of municipal waste utilization technology and embodying sustainable development in cities and towns.

3.7.2.6 Geothermal Energy Utilization

This indicator shows centralized heating (refrigeration) building area with direct utilization of geothermal energy, or ground source heat pump, surface water (sea, ocean, sewage) heat pump, air source heat pump as well as heat pump technology with thermal power plant circulating cooling as heat source.

According to the indicator, by the end of planning period, building area of excessive geothermal heating (refrigeration) and heat pump heating (refrigeration) should be more than 300 thousand square meters.

3.7.2.7 Utilization of Other New Energy

In addition to above-mentioned new energy utilization, cities and towns are encouraged to use new energy with other means or technologies. The indicator requires an accumulated amount of other new energy utilization of no less than 5,000 tons standard coal per year.

4 Best practice of Yanqi Lake Project

(Pictures of this chapter are provided by Beijing Enterprises Group Real-estate Co., Ltd)

4.1 Yanqi Lake: the 2014 APEC Economic Leaders' Meeting Venue

The ecological system of Beijing Yanqi Lake International Conference Center Project was built according to the concept ‘low-carbon, natural ecology, energy conservation and water saving’.

During the construction of Yanqi Lake Eco-development Demonstration Site, a bunch of advanced eco-development technology are applied to maximally economize on land, energy, water, raw materials and protect the environment, which can be reflected in the following:

- Sustainability of ecological environment – protecting and utilizing the natural features of Yanqi Lake and its perimeter zone to increase air, noise and surface water quality standard, thus maintaining a favorable environment; enlarging per capita public green areas to enhance de-oxygenation and carbon sequestration capacity. Ensuring landscape diversity by selecting plants, mainly from local species.
- Sustainability of energy utilization – Actively employing solar energy and earth energy while combining local climate and resource condition so as to improve renewable energy resources use ratio; Using energy conservation materials and equipments in buildings comprehensively, which reduces unit area annual energy dissipation in buildings and largely lowers carbon dioxide emissions.
- Sustainability of water resources – Water-saving tubular products and tools as well as unified rainwater collection, reuse of reclaimed water, direct supply of purified water and other systems are used to maximally increase water circulation utilization efficiency; advocating water-saving lifestyle to reduce per capita fresh water consumption.
- Sustainability of solid waste treatment – Applying hazard-free, quantity-reducing and recycling treatment technology to solid waste and building waste vacuum collection system to realize separate waste collection,

circular utilization of resources and zero leak during storage and transportation, thus increasing waste recycling rate.

- Sustainability of building design – North-south building layout is mainly adopted according to features of Northern China and natural ventilation is advocated; sunshade, heat preservation, sound insulation and other environmental sound technologies are widely used to maximally increase building energy efficiency and reduce unit area construction energy consumption.

Specific contents related to low-carbon, energy-conservation, green, environmental protection and ecology of the project will be introduced in the following with examples of China National Convention Center and Yanqi Lake International Conference Center.

Tab. 4-1 National convention center

<table>
<tr><td rowspan="6">Green Building</td><td>Land-saving and outdoor environment</td><td>• Landscape plants diversity
• Greenbelt square and sidewalk permeable pavement</td></tr>
<tr><td>Energy conservation and utilization</td><td>• Combination of ground source heat pump and ice-storage system
• Solar photovoltaic generation system
• Elevator energy-conservation control system
• LED lighting
• Combination of Underground Pipe Air system and PM2.5 treatment system
• Thermal pressure ventilation
• Eave sunshade
• Water curtain cooling</td></tr>
<tr><td>Water saving and utilization</td><td>• Rainwater collection system
• Reuse of reclaimed water
• Gardens and landscapes water-saving irrigation system</td></tr>
<tr><td>Raw materials saving and utilization</td><td>• On-site concrete are pre-blend commercial concrete
• Building wall insulation materials are new inorganic insulation materials of high efficiency
• Mortars are pre-blend
• Employing building materials and products that are currently generalized in Beijing
• Using recyclable materials and building materials made from waste</td></tr>
<tr><td>Indoor environment quality</td><td>• Indoor air quality monitoring system
• Underground space light guide lighting system
• Energy-saving lighting automatic control system</td></tr>
<tr><td>Operation management</td><td>• On-the-spot disposal of kitchen waste
• Energy-saving comprehensive management and display system
• Building intelligent lighting system
• Heat metering and temperature control system</td></tr>
<tr><td>Others</td><td colspan="2">Green transportation, carbon accounting and carbon-neutral, etc.</td></tr>
</table>

4.2 Recyclable Resources Application in Yanqi Lake

4.2.1 Ground Source Heat Pump

The technology applied in this project is single well recharging, which is innovated independently in China to use the terrestrial heat of shallow soil layer as heat source in winter and cold source in summer. Multiplexed energy system is employed according to the site condition. In winter, ground source heat pump plus heating boiler peak regulation can supply heat; in summer, refrigeration is realized by ground source heat pump + water chilling unit peak regulation. The installed capacity of the ground source heat pump is about 3600KW, which alone can satisfy 90% of winter heating demand and 75% of summer cooling demand, saving about 374 tons standard coal per year.

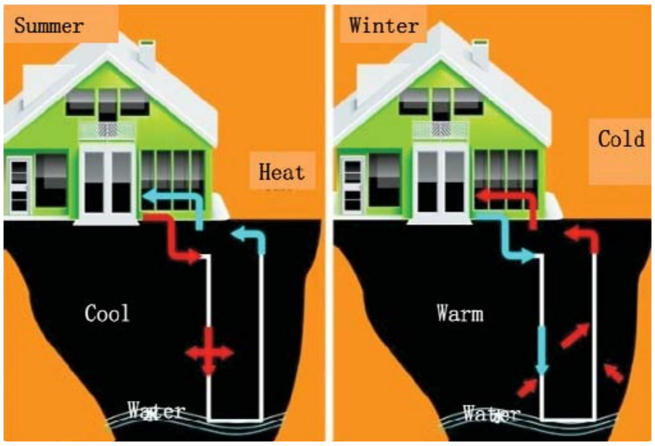


Fig. 4-1 Single well recharging technology

4.2.2 Solar photovoltaic Generation

To match the outdoor landscape design, approximately 2,000 square meters solar photovoltaic panels are installed at the gully in the east, generating enough power for daytime lighting of most areas inside the building. This can save about 34 tons standard coals per year, and reduce about 122 tons carbon dioxide emissions.

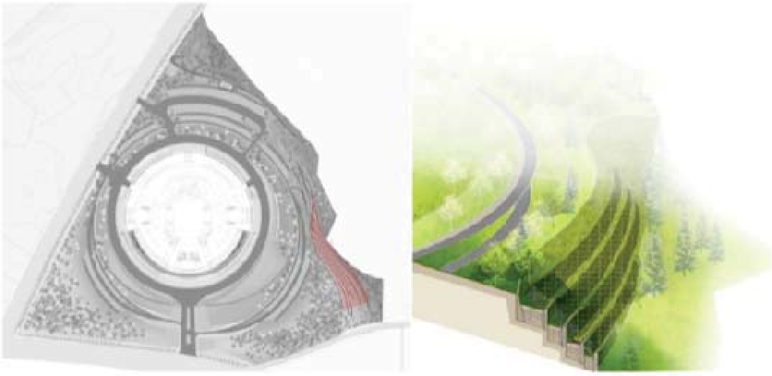


Fig. 4-2 Solar photovoltaic generation

4.2.3 Solar Water Heater

About 600-square-meter tiled solar thermal collectors of heat pipe vacuum tube are installed on roof, setting up the most advanced closed system which can provide about 40 tons heat water, saving about 63 tons standard coal and reduce carbon dioxide emissions by about 100 tons.

Fig. 4-3 Solar thermal collector

4.2.4 Light Guide Lighting

Light guide lighting refers to the technology of using light guide materials (light-pipe or fiber-optical) to guide sunlight indoor, which is healthy and energy-efficient. In the VIP Room of the convention center, light guide fiber is used to introduce sunlight indoor, providing four light windows to meet lighting demand of the VIP Room.

Fig. 4-4 Light guide lighting technology

4.3 Energy-conservation

4.3.1 Passive Technology

4.3.1.1 Natural Lighting

In addition to central lighting window and annular day-lighting band, a sundial clock is also designed in this project to present traditional Chinese features; sunken gardens are built in some part of southern ground floor, which can largely reduce lighting energy consumption in sunny days. According to the analog computation, favorable natural lighting can be thus achieved. Besides, most part of the banquet floor can reach the general requirement of office illumination

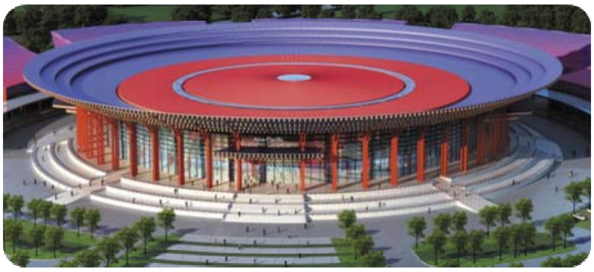
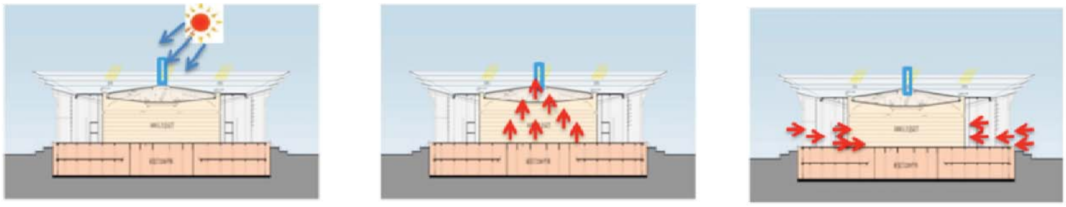


Fig. 4-5 Central lighting window and annular day-lighting band

4.3.1.2 Natural Ventilation

Fresh air enters through the side window of glass curtain wall surrounding the building. Since temperature of the roof window and annular window rise under the sun, a 'chimney' is thus formed to expel the hot air because of hot press. This process can improve indoor ventilation and increase ventilation rate. Analog computation of this system shows a favorable ventilation effect. In transitional seasons, 3.5 ventilations per hour can be realized.



1. Solar heating chimney 2. Heat out of the room 3. Fresh air into the room

Fig. 4-6 Natural ventilation system

4.3.1.3 Eave Sunshade

The project makes the best of the eave to realize building sunshade, keeping the sun off from the south by adjusting extending angel and length of the design. Analog computation of this design shows a favorable sunshade effect, with more than 8 hours' sunlight being totally kept off from the banquet floor of National Convention Center from all directions on Summer Solstice.

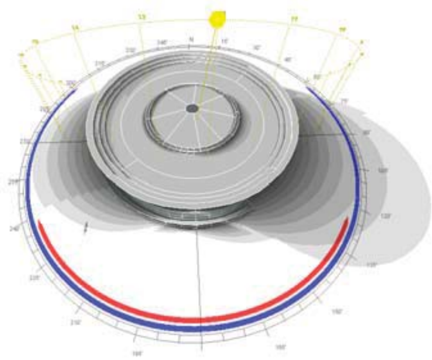


Fig. 4-7 Eave sunshade system

4.3.1.4 Underground Pipe Air

Underground pipe air refers to the technology of raising or lowering temperature through heat exchange between air and earth by laying underground pipes. In this project, two underground pipes which are 2.5 meters *2 meters in cross section and 65 meters long are buried 3.5 meters underground. Fresh air can only enter into the air conditioning unit after pre-cooling or pre-heating of the underground pipes. By analog computation, energy consumed by operation of the air conditioning unit are effectively reduced by the underground pipe air system, with up to 6 degree centigrade lowered in summer and 7 degrees centigrade raised in winter. The system can save about 20 tons standard coal and reduce carbon dioxide emissions by about 54 tons.

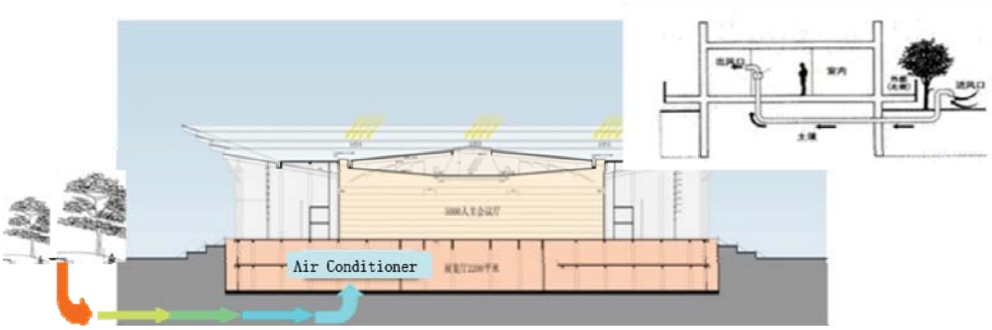


Fig. 4-8 Underground pipe air technology

4.3.1.5 Optimum Structural Design of External Building Envelope

Advanced tri-silver low-e hollow laminated glass is selected for the glass curtain wall, which can provide a comprehensive heat transfer coefficient of k=1.72W/ (m^2·K).

4.3.2 Active Technology

4.3.2.1 Lighting System Energy Conservation

- LED Lighting

LED is an efficient and energy-saving semiconductor solid luminescent device, which saves 80% energy compared to traditional light source yet enjoys 10 times of its service span. The color of LED can be flexibly changed and controlled. Moreover, there is no ultraviolet ray or infrared ray in its spectrum and it is recyclable after use. More than 80% indoor space of the convention center is equipped with LED lamps and intelligent lighting control system to achieve energy-saving lighting.

- OLED Lighting

The energy-saving efficiency of OLED is two times that of LED. OLED lamps are designed to some VIP restrooms as display.

Fig. 4-9 Energy-saving lighting system

4.3.2.2 Elevator Energy Recovery

The gravitational potential energy released during elevator descending can be recovered and transferred into power energy, which can be used for lighting inside the elevator cab. Energy recovery display screen can be installed to strengthen demonstrating effect.

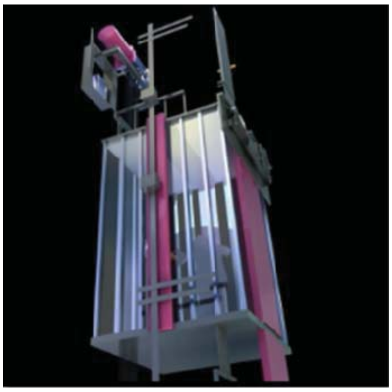


Fig. 4-10 Elevator energy recovery

4.4 Environment Protection

4.4.1 Water Environment Protection

4.4.1.1 Rainwater Infiltration and Recycling

Water permeable bricks are used in side, walk and activity space, and sunken Greenbelt is designed in greenbelt area. The outdoor permeable ground area ratio is more than 40%.

Fig. 4-11 Rainwater collecting system

Rainwater Collecting System includes rooftop rainwater collecting system and ground rainwater collecting system. Hydro-cone collecting is used to recycle rooftop rainwater and impounding reservoir is employed for ground rainwater collection. The collected rainwater can be used for greenbelt and landscape demand after infiltration and sterilization. Rainwater collection pool is assembled with environmentally-friendly polypropylene modules.

Fig. 4-12 Rainwater collecting system in construction

4.4.1.2 Reuse of Municipal Reclaimed water

Municipal reclaimed water can be reused in street cleaning, fire fighting, landscape planting, and cars washing, etc.

4.4.1.3 Water-saving Landscape Irrigation

Sprinkling irrigation, trickle irrigation and other irrigating methods together with auto-induction according to soil moisture content are adopted to realize water-saving irrigation.

Fig. 4-13 Landscape irrigation system

4.4.2 Air Environment Protection

4.4.2.1 PM 2.5 Elimination

- Central Vacuum

The central vacuum system is made up of cleaner main engine, duct, socket, and other component elements. The main engine is installed in the machine room at the second floor underground; and the inlet is set on ground, integrating with the carpet of the banquet floor and media floor. Compared with traditional hand-held cleaner, central cleaner can provide better cleaning effect (absorbing particulate matters with diameter larger than 0.1 micrometer, while PM2.5 refers to particulate matters with diameter less than 2.5 micrometers) and prevent secondary pollution of dust with lower noise. This system works well for the elimination of indoor PM2.5.

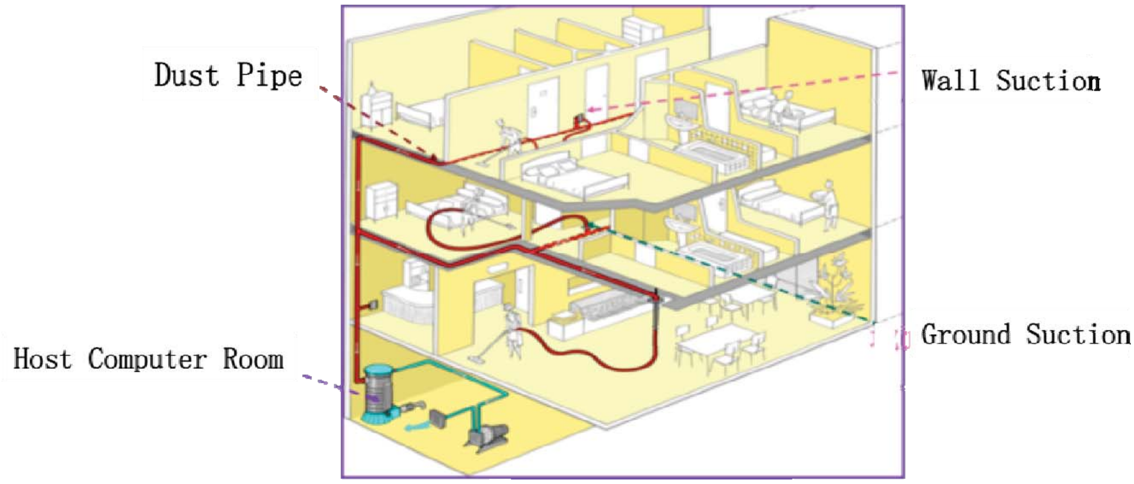


Fig. 4-14 Central vacuum system

- Air Conditioner Air Purification

In order to improve indoor air quality, several air purifying measures are taken at the air treatment part of air conditioning unit where fresh air enters, including filtration, ultraviolet sterilization activated carbon deodorant (to drive out hazardous substance in the air), and bipolar high voltage electrostatic precipitation, etc. Thus PM2.5 can be kept out of door from the source.

Fig. 4-15 Air conditioner air purification system

4.4.2.2 Indoor Air Quality Monitoring

Carbon dioxide concentration monitoring system is applied to the banquet hall and meeting room to achieve automatic ventilation adjustment, thus guaranteeing a healthy indoor air environment. For underground garage, carbon monoxide concentration monitoring system together with fresh air system can ensure a healthy air environment.

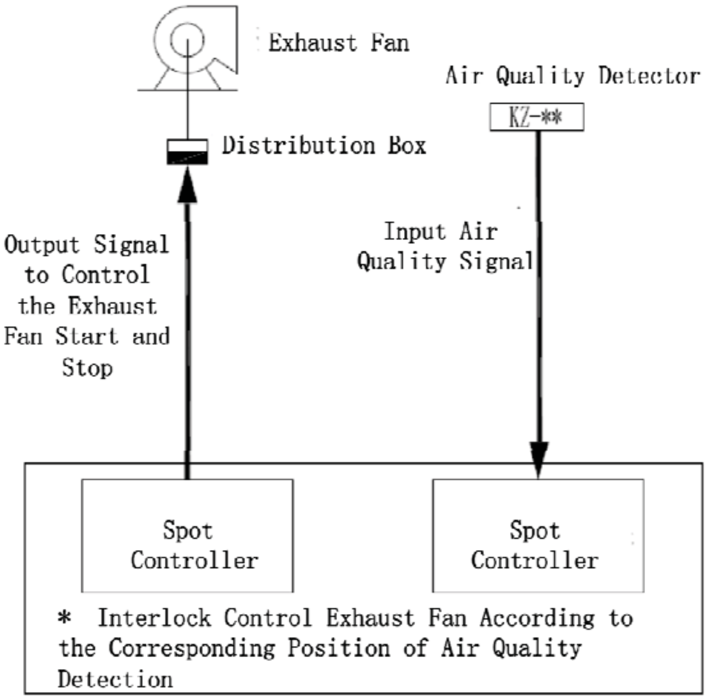


Fig. 4-16 Indoor air quality monitoring system

4.4.3 Solid Waste Treatment

4.4.3.1 Separate Waste Collection

Household waste is separated in the convention center as recyclable waste (waste paper, plastic, glass, metal, and cloth, etc), unrecyclable waste and beverage bottles. Moreover, several beverage bottles recycling machine, which will reward commemorative coins for bottles, will be installed in public areas. The unrecyclable will be transported to Huairou Wolvjie Household Waste Treatment Plant, while the recyclable will be separately transported by recycling enterprises.

4.4.3.2 On-the-spot Treatment of Kitchen Waste

After treatment including sorting, dehydration, oil water separation, stir, aerobic biological treatment, and exhaust gas deodorization, etc., kitchen waste will become fertilizer through aerobic compositing, saving 90% waste (10% counted as fertilizer). With 2000 people dining at the convention center at peak time, about 400 to 500 kilograms waste will be produced each day. Therefore, the equipment with actuate daily capacity of 500 kilograms will used.

Fig. 4-17 Kitchen waste treatment system

4.5 Low-carbon Energy Efficiency Management

4.5.1 Comprehensive Energy Efficiency Management Display System

A comprehensive energy efficiency management display system will be set up to collect data related to energy, transportation, weather, water for analysis and forecast, which will be useful for enterprise energy-conservation management, future risk early warning, and carbon accounting, etc. The system will be combined with Internet of Things to achieve the function of real-time remote inquiry of data.

Fig. 4-18 Energy efficiency management display

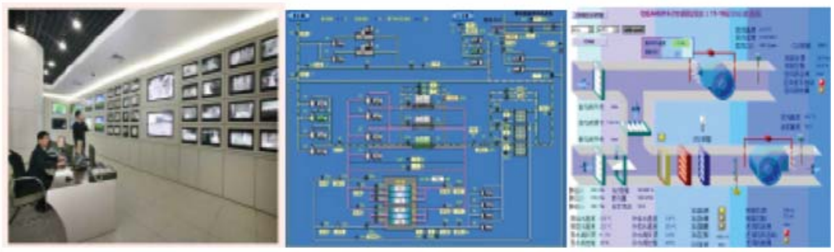


Fig. 4-19 Energy efficiency management display system

4.5.2 Carbon Accounting and Carbon-neutral

Carbon emission during construction of the convention center will be calculated and enterprise carbon accounting report will be compiled according to ISO14064 Standard. Moreover, an internationally known third party will be invited to examine the accuracy of the carbon accounting data. Accordingly, certain amount of carbon emission reductions will be bought from Beijing Environmental Exchange to neutralize the carbon emission during construction period.

5 Energy Internet

Intellectualization and decentralization of grid is inevitable due to the demand for stable, efficient and safe grid, as well as large-scale substitution of fossil energy by new and renewable energy represented by wind and solar photovoltaic. This trend is now gradually transferring from metaphorical 'Internet grid' to real Energy Internet, which manages the basic product of modern civilization – electricity power via Internet, cloud computing and big data technology. Electricity is to modern industry and consumption what Internet technology is to grid, with the former working as central nervous of the latter.

Energy Internet indicates the future of both energy and Internet. U.S. DOE expects that grid will be the combination of electric flow and information flow by the end of 2030. According to the goal set in policies carried out by President Obama, in 2035, 80% power generation of the U.S. will come from clean energy, the grid connection of which is key issue related to intelligent grid development. Currently, China government is compulsively popularizing clean energy and distributed power grid. As a result, mark-oriented reformation of grid is put on the agenda again.

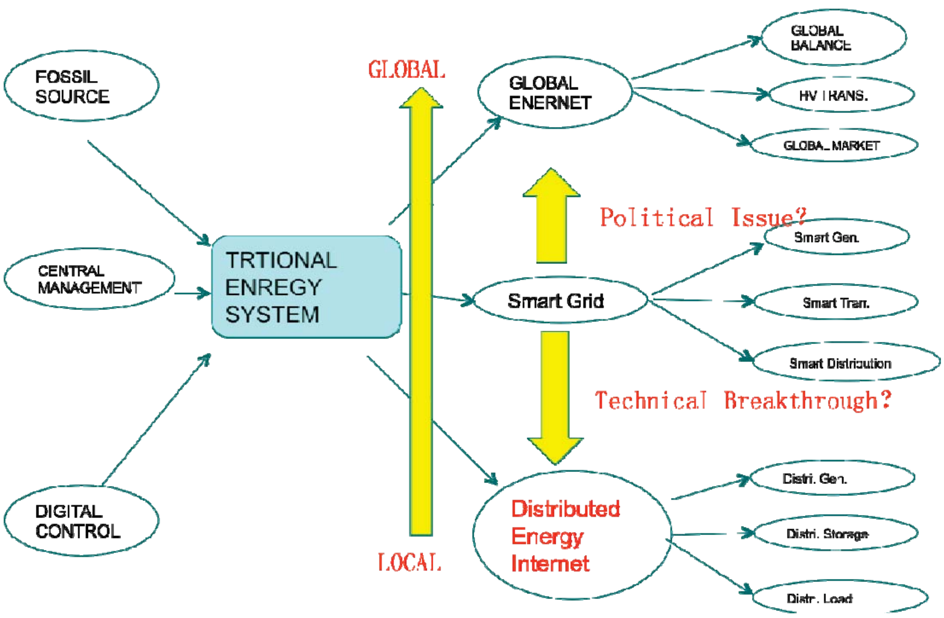


Fig. 5-1 Trend of future low carbon energy system

(Source: You Zhou, National Institute of Clean and Low Carbon Energy (NICE))

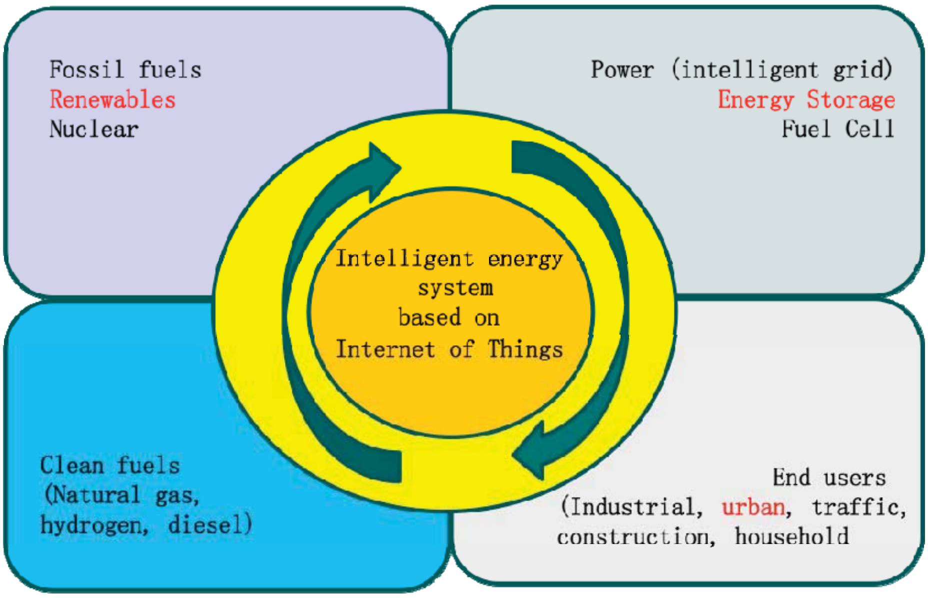


Fig. 5-2 Concept of intelligent energy system

(Source: You Zhou, National Institute of Clean and Low Carbon Energy (NICE))

5.1 Energy Internet Brief

Energy Internet is an interconnected sharing network of equal Energy via which bilateral flow of energy and information can be realized. It works on the basis of distributed energy, which can be achieved by integration of large amount of distributed renewable energy power generation devices and distributed energy storage devices with the help of advanced electric technology and information technology based on current grid.

Energy Internet is a new type of wide area network (WAN), which integrates information and energy under the theory of Internet. Supported by bulk grid power as 'backbone network', micro grid as 'local area network', together with open and equal information energy integration framework, it can realize bilateral on-demand transmission and dynamic balanced utilization of energy and maximally adjust to access of new energy.

As a fundamental element of Energy Internet, Micro grid can form LAN via new energy power generation, micro energy collection, convergence and sharing as well as energy storage or power consumption inside the micro grid. Energy Internet is transferring a centralized unidirectional grid into a grid that enables more customer interaction.

Instrumentation: operation of sensors, meters and instrument monitoring equipment, energy utilization, equipment condition, system performance and environment conditions.

Interconnection: the integration of equipment, measuring and controlling system and assets management system provides a top-bottom and bottom-top view directing at equipment performance, energy utilization and cost as well as carbon footprint.

Intellectualization: advanced analysis will examine and diagnose troubles, provides information about cost saving, and helps staff to forecast possible problems before building performance and residents are affected.

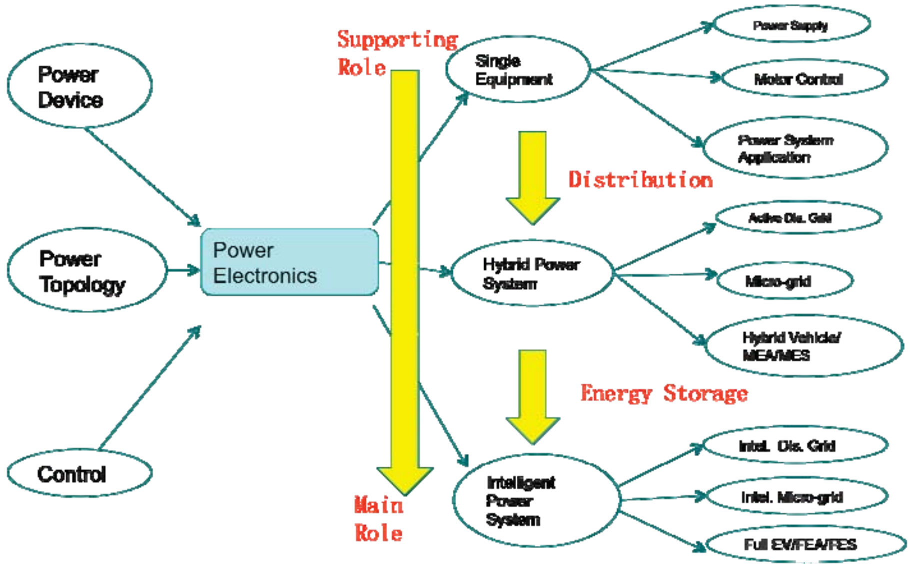


Fig. 5-3 Challenge of power electronics for Energy Internet

(Source: You Zhou, National Institute of Clean and Low Carbon Energy (NICE))

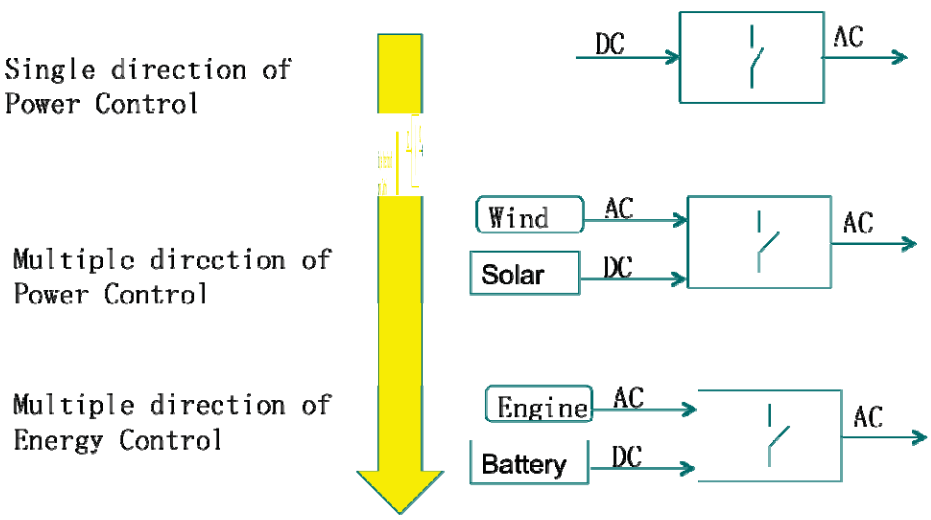


Fig. 5-4 Development trend for power (energy) control

(Source: You Zhou, National Institute of Clean and Low Carbon Energy (NICE))

5.2 Energy Internet Features

Following are five major features of Energy Internet:

- Renewable: renewable energy is the main supply source of Energy Internet. Since renewable energy power generation is intermittent and fluctuating, large-scale access of it will harm stability of the power grid, thus stimulating the transition from conventional energy network into Energy Internet.
- Distributed: due to the distributed characteristic of renewable energy, networks for energy collection, storage and utilization is required to be established in order to collecting and employing renewable energy with maximum efficiency. Small in scale and distributed in a wide range, each of those micro energy networks can be node of Energy Internet.
- Connected: each micro energy networks distributed in a wide range, though not being able to self-sufficient, can be combined to balance energy supply and demand through energy exchange. Energy Internet focuses on connecting micro energy networks that are made up of distributed power generation devices, energy storage devices and load, while conventional power grid pays more attention to ‘bring in’ these elements.
- Open: Energy Internet should be an equal and flat energy sharing network through which bilateral energy flow can be realized. With the Energy Internet, ‘plug and play’ of power generation devices, energy storage devices and load can be achieved with independent access as long as operation standards are followed. Moreover, from the perspective of energy exchange, the importance of each Internet node is equal.
- Integrated: existed conventional power grid should not be ignored during infrastructure construction of Energy Internet. Large investment of backbone network for conventional power grid in particular explains that infrastructure construction for conventional power grid should be reformed to be used in Energy Internet. Moreover, micro energy networks are supposed to be integrated into reformed bulk power grid, forming a new and large-scale energy sharing interconnected network.

5.3 Core Technologies of Energy Internet

5.3.1 Smart Grid Data Collection Technology

Big data can be used to describe and define the mass data produced during information explosion and name related technological development and innovation.

Smart collection terminal automatically collects information about big customer exclusive transformer, public transformer, and low-voltage residents' power consumption, realizing data collection of user side power consumption and load, electric device data collection and online diagnosis and supporting long-distance transfer of real time data.

5.3.2 Smart Grid Interactive Terminal Technology

Based on the principle of network, man-machine interaction, business and functions integration, and supported by network platform of power consumption information collecting system, smart interactive terminal displays power consumption information, style, alarm information, electrovalence policy and other related information directly to users.

In order to extend power consumption information collecting system communication network, several choices are provided, users can install liquid crystal power consumption display terminal at home. Directly connected household electrical circuit with collector or electric energy meter as gateway, it will monitor electric meter automatically via power line carrier to provide real time power consumption information and receive all information provided by user power consumption information collecting system. Moreover, users can inquire power consumption history, payment record, statistical graphic of historical data and other information with easy operation, so that they can have timely access to electricity consumption, electricity price, prepaid electricity charge, remaining electricity charge and other information. Users can also inquire electricity consumption information via various terminal devices (cell phone, Internet, etc.).

5.3.3 Smart Grid Demander Response Technology

Demander response technology refers to that power consumer response to power consumption load change after receiving the power consumption information provided by power suppliers, so as to realize peak load shifting and reduce load fluctuation. It has the following features:

- Actively taking part in market competition with users changing their own power consuming forms to earn corresponding economic benefit;
- Power supplier calling upon users to access or exit distributed power source based on load characteristic and making compensation settlement mechanism with users participating in demander response;
- Users receiving constant and timely metrical information, load information, and electricity price information;
- Providing real time electricity price for users and achieving automatic load controlling combined with real time electricity price;
- Compiling and releasing orderly power utilization program, remote monitoring power quality and controlling voltage, quick location and response of system faults and detecting energy loss;
- Providing accurate system load information for scheduling, planning and operation of the system and sharing information between new smart devices and premium services.

5.3.4 Intelligent Substation Technology

Intelligent substation: supported by Internet of Things technologies including sensor and real time big data platform, intelligent substation can carry out multi-function coordination of station supervision, online monitoring and intelligent auxiliary control, etc., which is becoming a standard designing orientation in China. While being integrated with cloud computing and real time big data, service programs related are basic maintenance measures including data collection, real time monitoring, signal interaction, and fault treatment, etc., in addition to reserving ports on the equipment.

5.3.5 Distributed Energy Smart Micro Grid

With distributed energy smart micro grid as core, several smart micro grids interconnect and interwork to establish Energy Internet in true sense.

Fig. 5-5 Distributed energy smart micro grid diagram

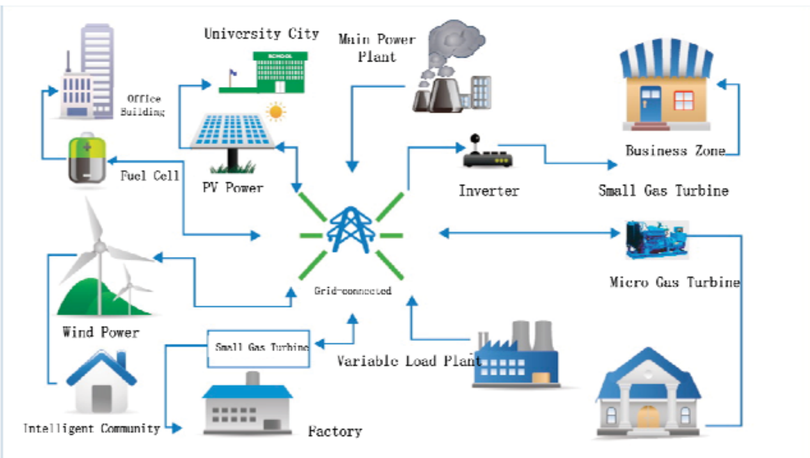


Fig. 5-6 Distributed energy smart micro grid

Smart micro cloud dispatching platform supports and coordinates dispatching personnel to direct safe, stable and economic operation of distributed micro grid. It mainly has the following three functions:

- Realizing secure operation of micro grid monitoring. While the micro grid is working normally, by monitoring and controlling all real time big data including cycle, voltage, tide, load, and output and real time operation condition indicators of distributed main devices including solar panels, windmill, heating and cooling, storage battery, and diesel engine, so as to follow the regulations and ensure power quality and electrical load.
- Realizing economic and optimal dispatching of distributed micro grid operation. Economic and optimal dispatching of distributed micro grid will be realized in the premise of secure monitoring of micro grid to reduce loss and save energy, thus realizing low cost power generation and supply.
- Carrying out safety analysis, faults diagnosis and treatment on micro grid operation. Factors leading to faults or abnormal operation of micro grid are usually complex and deteriorating. Without timely forecast, judgment and proper treatment, it can result in micro grid collapse and power-out, bring about devastating losses. As a result, real time big data analysis and diagnosis must be used via smart cloud dispatching platform to carry our early warning analysis, provide faults diagnosis strategy and related monitoring measures, so as to prevent faults and avoid or reduce losses.

Fig. 5-7 Wind-solar distributed energy micro grid experiment

(Source: The fourteenth of Wall Street financial observation phase: Future Energy Internet development trend of real-time large data)

5.4 Energy Internet Best Practice

5.4.1 China Advocating Blueprint of Global Energy Internet

In the annual meeting of IEEE PES held in July, 2014, State Grid Corporation of China put forward the suggestion of establishing global Energy Internet, and a globlly connected smart grid with high woltage grid as backbone network and clean energy transmission as major goal. Global Energy Internet, constituted by trans-continental and transnational backbone networks as well as power grid of different voltage levels, is connected to large scale energy bases as 'the actic pole and equator'. It can adjust to all kinds of centralized and distributed power source and transfer renewable energy including wind power, solar power and sea power to various users.

Electric boiler, electric heating, electric cooling and eletric cooker is advocated in terminal consumption with the goal of replacing coal with electricityby changing coal-consuming industrial boiler, industrial furnace and residents' heating and cooking into power-consuming so that direct fired coal can be reduced by large margin; electric transporatation, electric mobile and electrical agricultrual irragation is promoted to substitute petroleum with electricity. In order to replace coal with electricity, feasible replacement plan should be made accoring to clean energy development, environment treatment, green house gas (GHG) emission reduction goal, including technology improvement scheme comparison, investment estimation and electricity price incentive policy, etc.

As for replacing petroleum with electricity, in addition to further promotion of electric transmission, electric mobile should be developed as an effective means. However, electric mobile currently is not mature enough to be popularized in large scale with the major bottleneck of energy storage battery, which can only be improved with more scientific researches and development. Besides, charging and alternating networks should be planned and constructed in line with development of electric mobile.

Power grid of different levels should be planned in transmission and distribution sections. Extra-high voltage alternating current is mainly used for establishing national, continental and intercontinental power grid as well as long-distance high-capacity power transmission; while extra-high voltage direct current is generally used for constructing large-scale base over-distance extra-large capacity power transmission and major transnational and transcontinental passages. Since wind power and solar power generation enjoys smaller capacity and lower benefits compared to conventional power sources, construction scale of flexible power resources should be enlarged. With vigorous development of wind power and solar power generation, overall installed capacity of global Electricity will increase by large margin, and the investment scale of ultra-high voltage grid, supergrid and power distribution network will be increased significantly.

In power genration section, conventional power source should be well planned, constructed and operated in accordance with development of wind power and solar power generation. Moreover, the project is supposed to vigourously develop, demonstrate and apply new energy storage power sources in scale, accelerate the development of all flexible pneumoelectic and make the most of flexible power sources as pumped storage power station.

5.4.2 Internet Companies Marching towards Energy Sector

Though seemingly farfetched, Internet companies and energy industry is gradually integrating. For example, Google has made 15 investments in wind and solar photovoltaic section with a total of more than $1 billion. In the fourth quarter of 2013 only, Google invested $2.25 billion in green transforming of data center and infrastructure. On February 17th, 2014, Google invested in another solar energy project, that is investing to set up solar thermal electric project around Nevada, California. It is said that 3,470 thousand solar panels will be used to provide 392 megawatt electricity for 140 thousand families in California.

It is possible that enormous energy required for Google data center will be supplied by solar power or wind power in the future. In order to achieve this, not only Google itself but also a series of companies using Internet of Things (such as Envision Energy of China) are working hard to provide Google management technologies and resolutions based on Internet. Moreover, Google purchased Nest, a company founded by former Apple team to reinvent smoke alarm and room thermostat, which are connected to other smart home electric appliances with network, thus transferring energy saving management in accordance with family demanding response to smart home.

Google also offers a reward of $1 million to encourage the invention, designing and manufacturing of smaller power inverter. In the field of distributed energy, power inverter will reform the way power grid is accessed, just as modulator-demodulator changed the way telephone system is accessed. This could hugely change the photovoltaic system design and structure in future.

Fig. 5-8 Distributed energy efficiency management micro grid of Google Data Center

(Source: The fourteenth of Wall Street financial observation phase: Future Energy Internet development trend of real-time large data)

5.4.3 Pilot Garden Energy Internet Transformation

In the 3.2 million-square-foot Rochester Garden in Minnesota U.S., there are more than interconnected buildings, including production facilities, test labs, office buildings and a global data center. Therefore, a series of Energy Internet solutions are taken to reduce energy consumption and maintenance cost.

In the preliminary stage of this project, information of 87 largest and mostly-loaded air handling unit as well as lighting and perimeter heating of three buildings is integrated to provide valve and air door condition (such as open or closed), engine operation, temperature and speed and other equipment and environment parameter.

In the secondary stage of the project, staff will extend the application scale to cover the operating data of a total of 254 air handling unit. In the following stages, data of hundreds of facility assets including boiler, compressor, cooler, pump, stream hydrophobic valve and air-cooling tower will be integrated.

Data analysis and optimization software will measure and record operation performance according to related standards (rules) and highlight detected faults. A service request will be made automatically and related personnel will be informed once faults are detected. For example, if the temperature of outside air is higher than 70℃ while one hot gas valve of the air handling machine is open to supply unnecessary heat to the building, maintenance personnel can receive reminding in time so that he can solve the problem on site in person. In the past however, this kind of problem can only be found when building residents called to complain about the temperature.

6 Observation and Conclusion

The year 2014 is of great importance to the development of global Energy Internet, which will be significantly accelerated with innovative practices of APEC economies on EMS system, extra-high voltage, smart grid, new and renewable energy. Under this background, the development of EMS shows the following features:

6.1 Two Replacements of Energy Supply Sector

'Clean replacement' and 'electricity replacement' are required to deal with numerous challenges including energy sustainability, environment pollution and climate change that confronts long term development of APEC region. Clean replacement means to replace fosil energy with clean energy, realizing transition from fosil energy supplemented with clean energy to clean energy supplemented with fosil energy; whereas electricity replacement is to carry out 'replacing coal with electricity, replacing petroleum with electricity' in energy consumption, improving electric energy ration in terminal energy consumption and reducing environment pollution and GHG emission.

6.2 Comprehensive Popularization of EMS

To realize efficient utilization, energy saving and emission reduction of conventional energy as well as reasonable utilization of combined conventional energy and new energy requires constant improvement of EMS. The development EMS will optimize energy production, transmission and consumption, reduce negative effects of energy industry pollution emission on the environment, and produce more efficient, more economic, safer and cleaner energy supply, thus realizing optimal distribution and efficient utilization of assets. With overall grasp and flexible allocation of energy, optimal distribution and management of energy assets as well as low-carbon energy system can be achieved. Moreover, sustainable development of low-carbon with low-carbon energy is supposed to be realized thanks to efficient utilization of energy and energy saving and emission reduction.

6.3 Interactive Management of User Side

By interactive management of user side, users actively participate in energy management while suppliers providing high-quality, convenient and value-adding energy service. Moreover, user participation energy management encouraging mode will be established to provide reliable services, including maintenance, payment, interaction and other convenient integrated services, multi-networks integration service based on Energy Internet, electric communication and information Internet, electric communication network, and cable television network, etc, and integrated service network of water, electricity, gas, thermal power, and cool air that seamlessly connected user terminal.

6.4 Establishing Energy Trade Platform and Flexible Exchange Mechanism

In addition to international petroleum and other conventional energy trade platform, regional energy trade platform and mechanism is of increasing importance with popularization of EMS. By establishing flexible exchange mechanism and energy pricing system of market-oriented intelligent multi-energy interaction, various convenient conditions can be provided for energy exchange so as to promote development of energy market-oriented exchange as well as coordinated utilization of multi-energy.

6.5 Joint Development of Energy Internet

Future energy industry system will establish user side system and transform towards green, economic and efficient energy. Therefore, Energy Internet development is a great developing opportunity faced by all APEC economies. With Energy Internet, users can interact and communicate with energy market via customized energy utilization mode, thus realizing maximal industrial value. Thanks to Energy Internet interaction, users, being clients and small-size power suppliers in the meantime, can carry out better management of demand and reduce energy utilization cost, together with energy producer, thus promoting energy system within APEC region towards green, economic and efficient system.

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