

Wind Photovoltaic Storage renewable energy generation technology, development and construction model

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Lecturer Profile



Wang Jun

Senior Engineer.

- ★ Chief project design manager of renewable energy department of PowerChina Zhongnan
- ★ Engaged in renewable energy industry in 2013, involving engineering design in PV plant, wind power, BESS, hybrid system and many other fields.
- ★ Worked in project design in China, Algeria, Morocco, South Africa, Bangladesh, Nepal, Vietnam, Thailand and other countries. Served as the project designer manager of many PV plant, wind power and hybrid system projects.
- ★ Won the Excellent Engineering Survey and Design Award of Hunan Province, the "Excellent Engineering Consulting Award in the Power Industry" of China Electric Power Planning & Engineering Association (CEPPEA), the "Excellent Engineering Design Award in the Power Industry" of CEPPEA, the "General Contracting Award for Excellent Engineering in the Power Industry" of CEPPEA, "China Construction Engineering Luban Prize", and the "High quality project award" of PowerChina Group Limited.

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and characteristics



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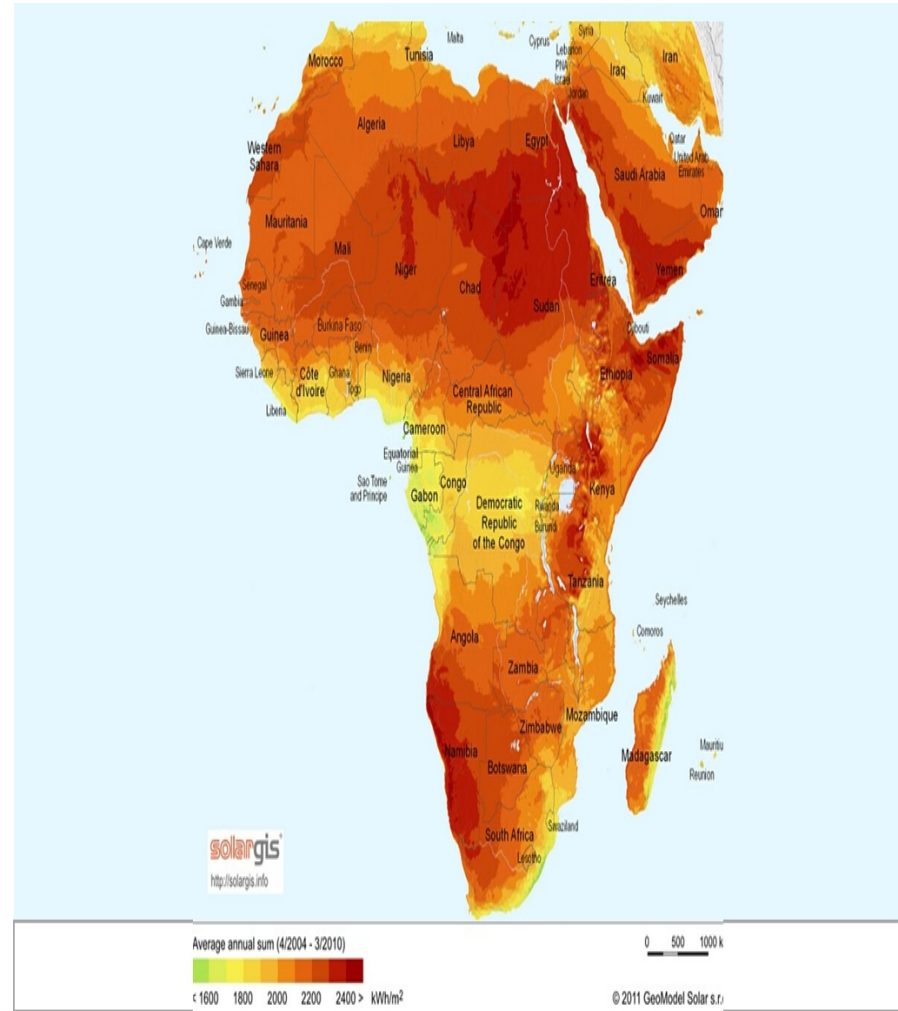
Typical cases



1 PV power generation technology and characteristics

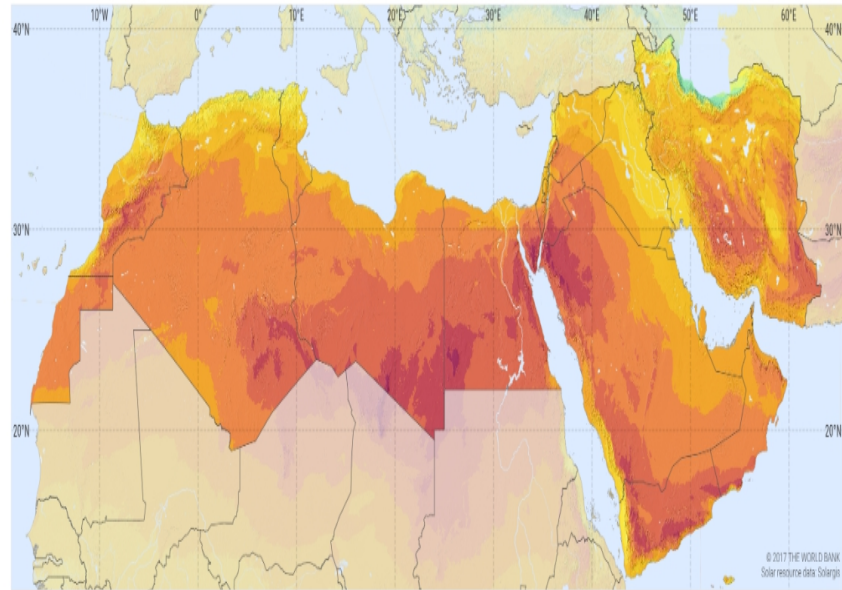
1.1 Africa's solar energy resource

- The solar energy resources throughout Africa are very rich and highly available. The regions with the most abundant solar energy resources are the Sahara region, the Ethiopian Plateau and the South African Plateau.
- The total global horizontal radiation in the Mediterranean coastal region of Africa ranges from 1709.1 to 1788.5 kWh/m².
- With the Sahara as the center, it extends eastward to Sudan, Ethiopia, Somalia and northern Kenya and Tanzania in the east, as well as Namibia, South Africa and eastern Botswana in the south of Africa. The solar energy resources are the most abundant, with the global horizontal total radiation reaching 2110.7~2425.3 kWh/m².
- The central region of West Africa is the lowest, and Gabon, Congo, Democratic Republic of the Congo and northern Angola have the total global horizontal radiation in the range of 1511.1~1805.4 kWh/m²



1.2 North Africa's solar energy resource

MIDDLE EAST AND NORTH AFRICA



Long term average of PVOUT, period from 1994 (1999 in the East) to 2015

Daily totals:	3.6	4.0	4.4	4.8	5.2	5.6
	kWh/kWp					
Yearly totals:	1314	1461	1607	1753	1899	2045

This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit <http://globalholaritas.info>

North Africa

Morocco, Algeria, Tunisia, Libya and Egypt have great potential for solar thermal power generation.

The total annual solar radiation in Algeria is 9720MJ/m², and the annual technological development is about 169440TW • h. The total annual solar radiation of Morocco is 9360MJ/m², and the annual technological development is about 20151TW • h.

The total annual solar radiation in Egypt is 10080MJ/m², and the annual technological development is about 73656TW • h.

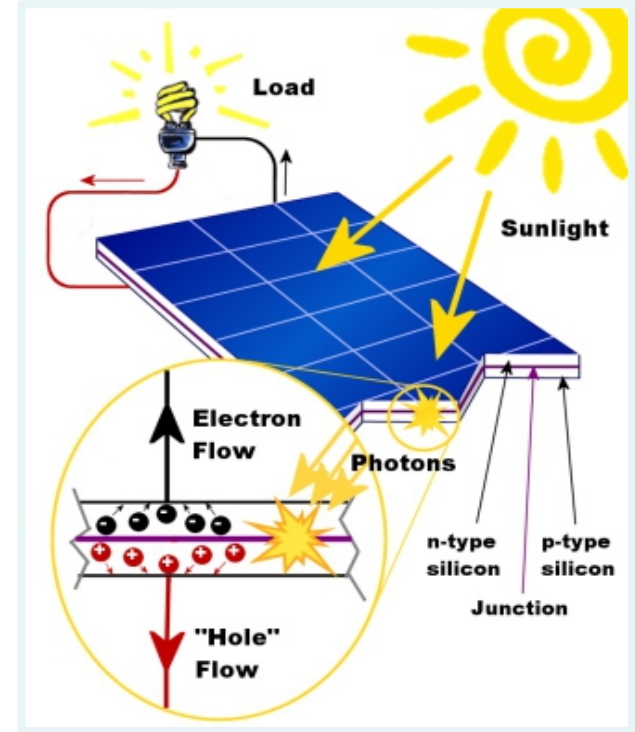
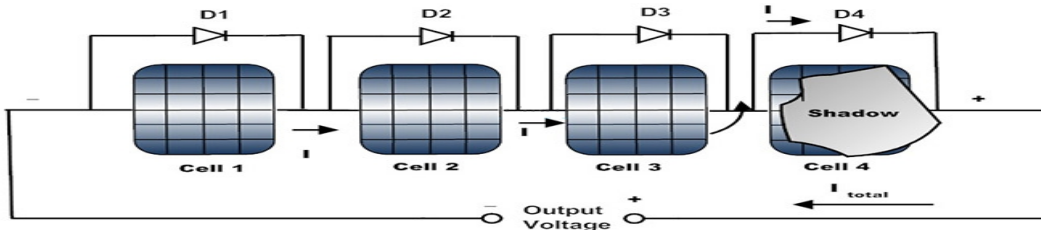
Tunisia, Libya and other countries have annual total solar radiation greater than 8280MJ/m².

Algeria has a land area of 2381.7km², with an annual total solar radiation of 6120MJ/m² in coastal areas and 6840-9540MJ/m² in highlands and Sahara. 82% of the total land in the country is suitable for the construction of solar thermal power stations.

1.3 PV power generation principle

Photovoltaic effect

- Convert solar energy into electricity.
- When the light shines on the surface of the solar cell, part of the photons are absorbed by the silicon material, which makes the electrons transition and become free electrons. The free electrons gather on both sides of the PN junction to form a potential difference. When the external circuit is connected, under the effect of this voltage, a current will flow through the external circuit to produce a certain power output. The essence of this process is that photon energy is converted into electrical energy.



1.4 Inverter

- **Function**
Invert DC to AC.



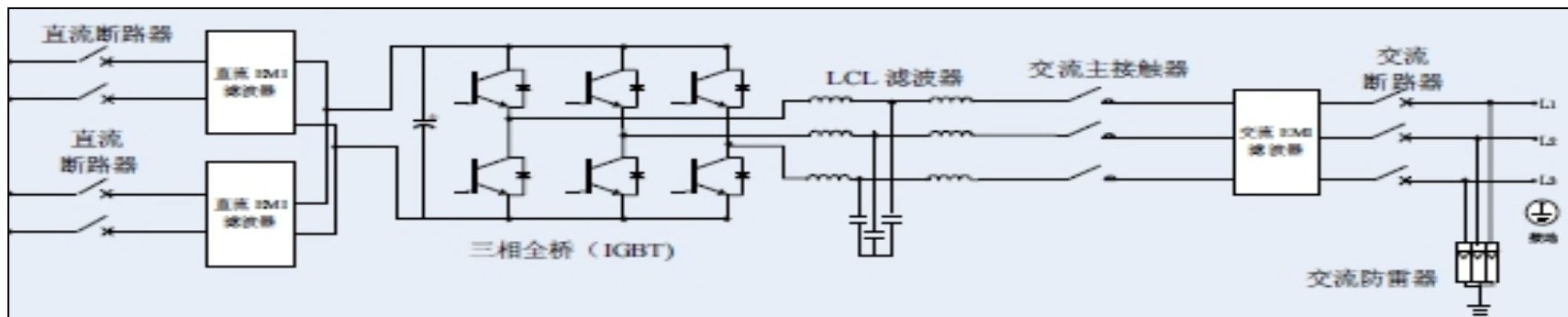
Type 1: Centralized inverter



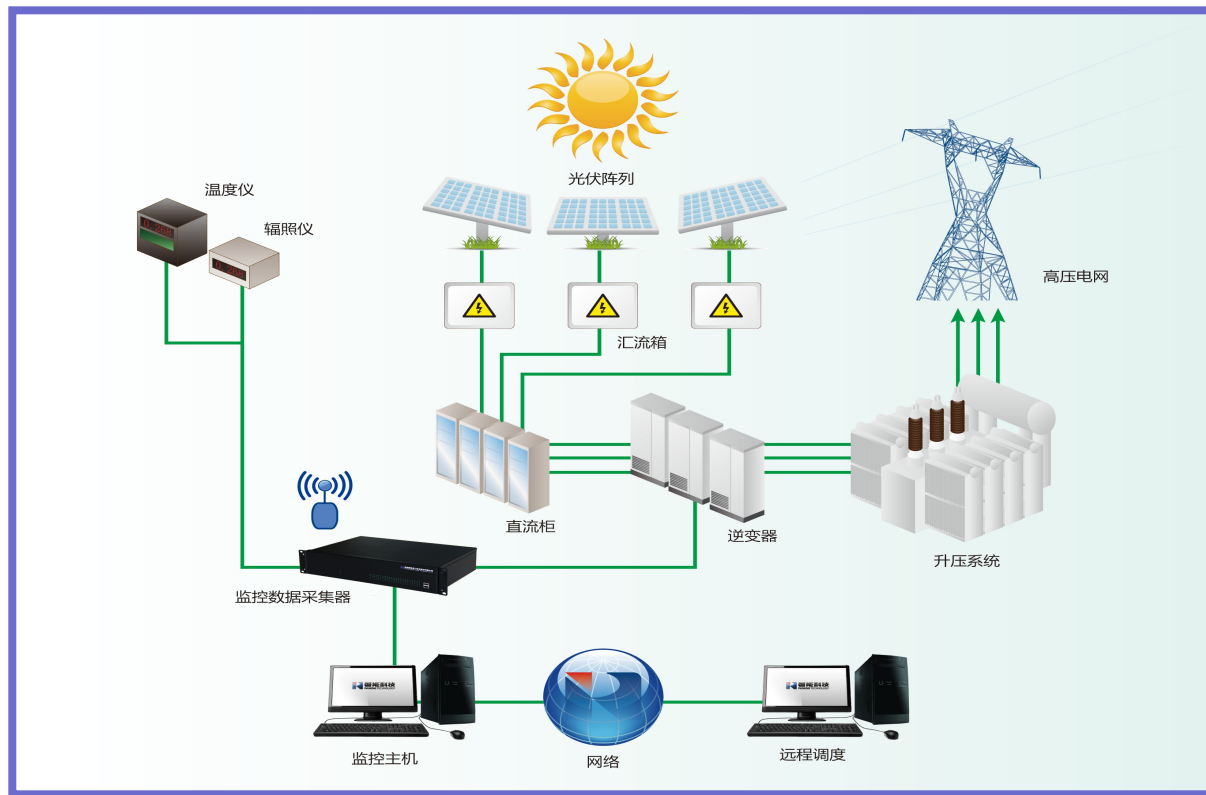
Type 2: Distributed inverter



Type 3: String inverter



1.5 Structure of photovoltaic power generation system



Main equipment

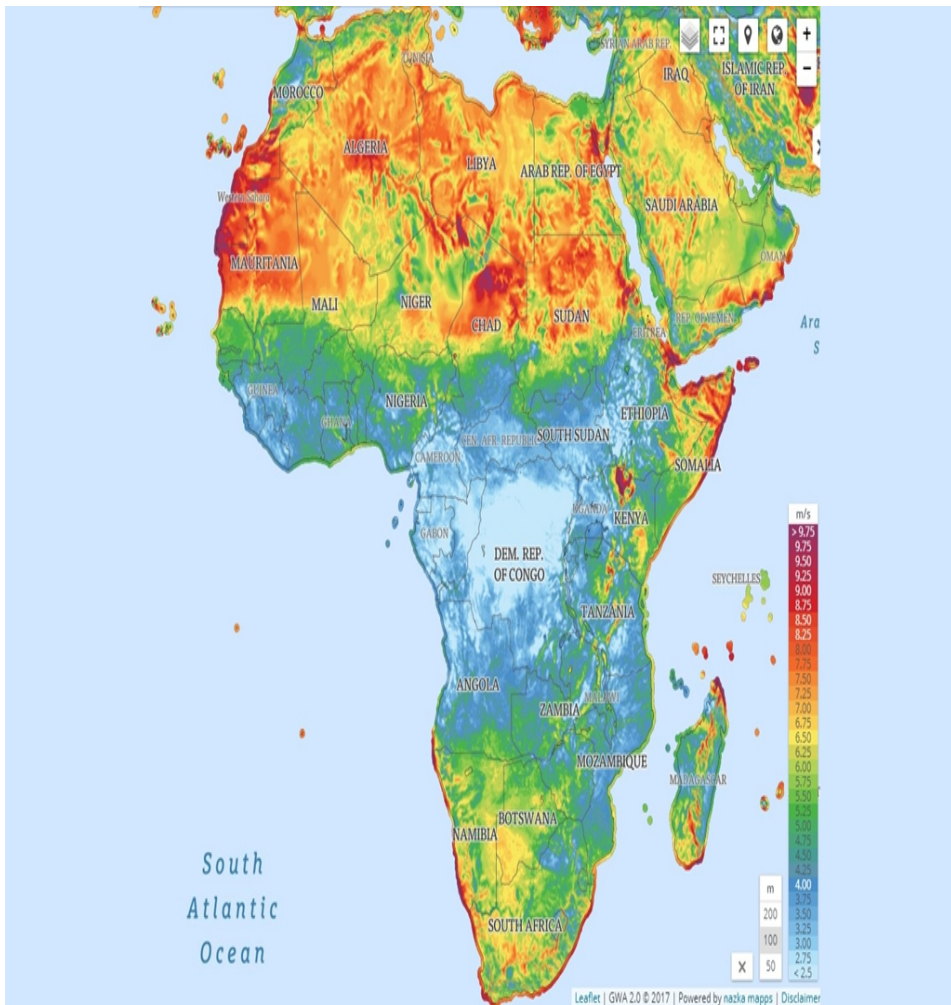
- PV Array
- Combiner Box
- DC Combinet
- Inverter
- Srep-up equipment
- Local Grid
- DC/AC cable
- Monitoring and communication device



2 Wind power generation technology and characteristics

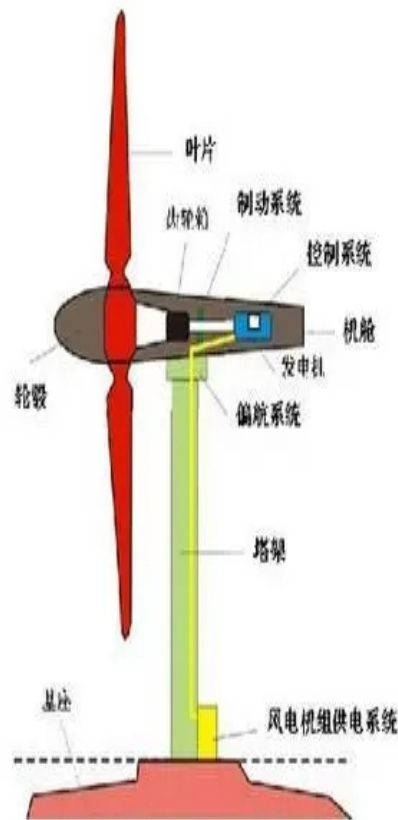
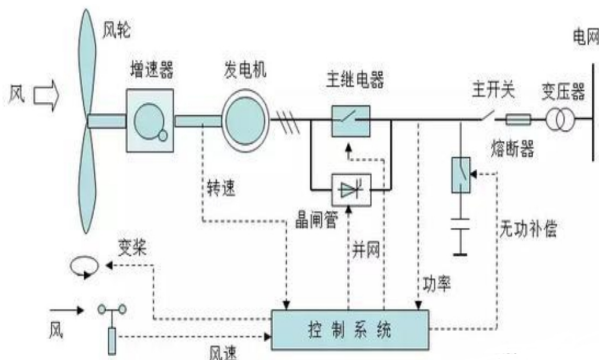
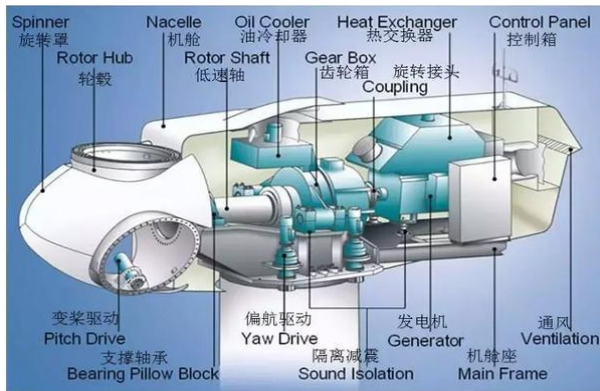
2.1 Africa's wind energy resource

- Africa is rich in wind resources. The concentrated area is mainly divided into two parts, the Sahara Desert and its northern region and the southern coastal region.
- The Sahara Desert and its north area are mostly desert terrain with flat and open terrain, so the wind speed is relatively high, basically above 6 to 7m/s.
- The land area south of the Sahara Desert is relatively poor in wind resources, with low wind speed. Most areas are below 5m/s, and some areas are even less than 3m/s. Only South Africa has good land wind resources, with wind speed of more than 7m/s.
- The wind speed in the south coast of Africa is high, reaching more than 8~9m/s, and the wind speed in the middle east coast is also high, reaching 6~7m/s, with relatively large wind resource reserves.



2.2 Wind power generation principle

- The wind power generation system uses the wind to drive the windmill blades to rotate, and then increases the rotation speed through the booster engine to promote the generator to generate electricity.
- Wind power generation is the process of converting wind energy into mechanical energy, and then converting mechanical energy into electrical energy.
- This process requires no fuel, no radiation, and no air pollution. It is a clean energy.





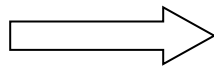
3 Micro-Grid technology

3.1 Practical problems encountered in Wind power and PV power generation

- Safety/life of electrical equipment — Power grid assessment penalty and network voltage rise
- Power grid assessment penalty — Change of power factor
- Risk of tripping — Power grid protection acts
- Additional investment — Increase of access equipment
- Power quality — Harmonics

Wind power and PV power generation

Intermittent , unstable, difficult to control



“Unfriendly electricity”

3.2 Definition of Micro-grid

■ European Commission Project Microgrids (NCPM)

Using primary energy and micro power supply, it can be divided into three types: uncontrollable, partially controllable and fully controlled, and it can supply cold, heat and electricity together. Equipped with energy storage device, the power electronic device is used for energy regulation.



■ The Consortium for Electric Reliability Technology Solutions, CERTS (CERTS)

Microgrid is a system composed of load and micro power. It can provide both electricity and heat. Power electronic devices are mainly responsible for energy conversion and provide necessary control for the power supply in the microgrid. Compared with the main power grid, the micro grid is a single controlled unit, which can simultaneously meet the user's demand for power quality and power supply security.



■ The New Energy and Industrial Technology Development Organization (NEDO)

Microgrid refers to a small system that uses controllable distributed power sources in a certain area to provide power according to user needs.



Based on the research results at home and abroad, micro-grid refers to one micro power supply network that is based on distributed generation technology, mainly uses decentralized new energy, and uses energy storage and control devices to achieve the balance of power and electricity within the network. Essentially, it is the application of new technologies in distribution networks and an important component of smart grids.

3.3 Micro-Grid's characteristics

Micro

Low voltage level, generally below 10kV; The system is small in scale, generally at megawatt level and below; Connect with the end user, and use the electric energy locally.

Self balance

During grid connected operation, the power supply and load in the microgrid are basically balanced, and the power exchange with the external grid is very small. The self balance rate of the electric power of the micro grid should generally be above 80%.

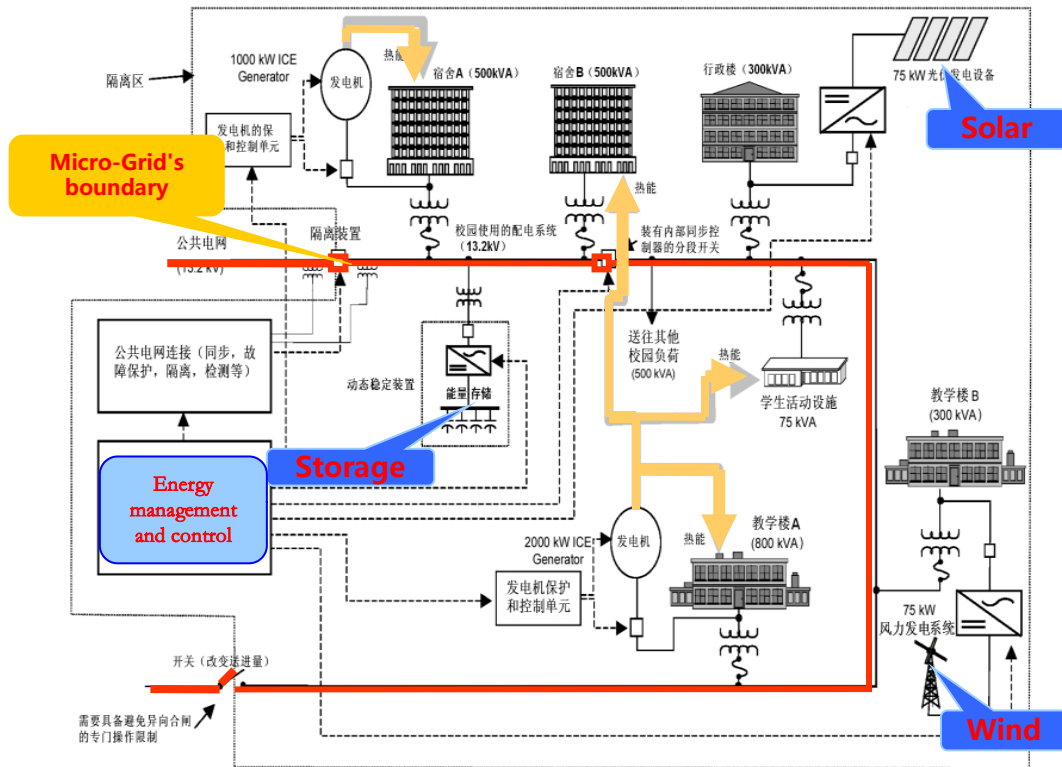
Smooth switching

When the main power grid fails, the micro grid automatically turns to independent operation status; When the external power grid recovers power supply, the microgrid automatically recovers its connection with the main network. Internal users can not feel the power supply interruption during the switching process, which can improve the power supply reliability.

Clean efficient

The distributed power generation in the micro grid is mainly based on clean energy, or is a form of power generation aiming at the comprehensive utilization of energy. The comprehensive utilization rate of fossil energy should generally be above 70%.

3.4 Structure and characteristics of Micro-Grid



Structure:

- Power (Wind、Solar)
- Storage (Electricity, Heat)
- Load (Cool, Heat, Electricity)
- Energy management and control.

Sharacteristics:

- Meet the comprehensive energy demand.
- Grid exchange power control.
- Dual mode of independent grid and integrated grid.

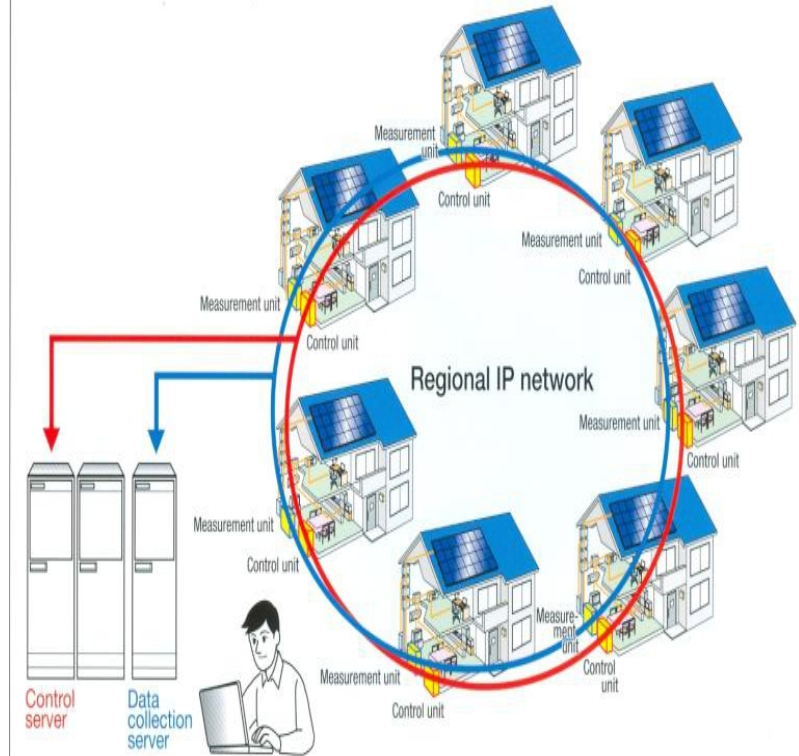
3.5 The role of Micro-grid

- Mitigate the impact of high-density photovoltaic and wind power on the power grid;
- Realize cascade efficient utilization of multiple energy sources;
- Provide customized power supply service for users;
- Provide important power supply support for power grid fault self-healing;
- Solve reliable power supply in remote and remote areas.

■ It is an important basic unit of energy Internet.

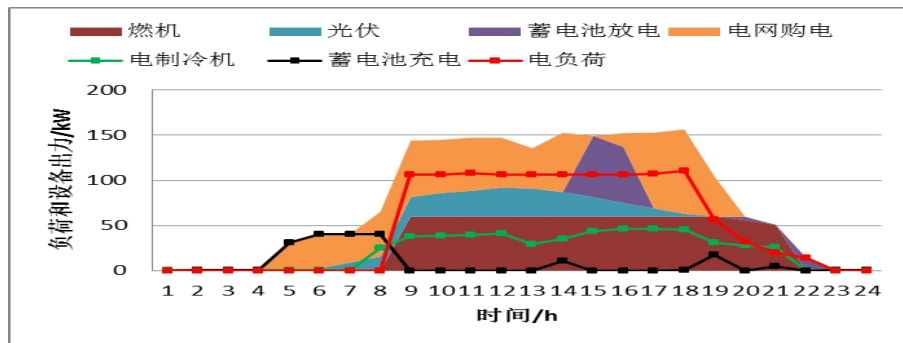
3.6 Development and construction mode(1) - User/community micro grid dominated by renewable energy

- **Power supply:** Wind/Solar/Storage/etc.
- **Application scenario:** High density photovoltaic and wind power access areas, new urban communities.
- **Purpose:** To reduce the impact of wind power and photovoltaic access system, increase the utilization ratio of renewable energy, and use renewable energy according to local conditions.



3.6 Development and construction mode(2)- Integrated energy Micro-grid

- **Power supply:** Wind/Solar/Storage/Geothermal heat pumps/etc.
- **Application scenario:** Energy stations, large public buildings, schools, hospitals, etc.
- **Purpose:** Highly combine with building/community energy-saving technology to improve the comprehensive utilization efficiency of energy and realize the cascade utilization of energy.



**Gas generator+Solar+Battery+Heat Storage+GHP+Others =
Cool/Heat/Electricity/Storage Integrated energy supply system(Micro-grid).**

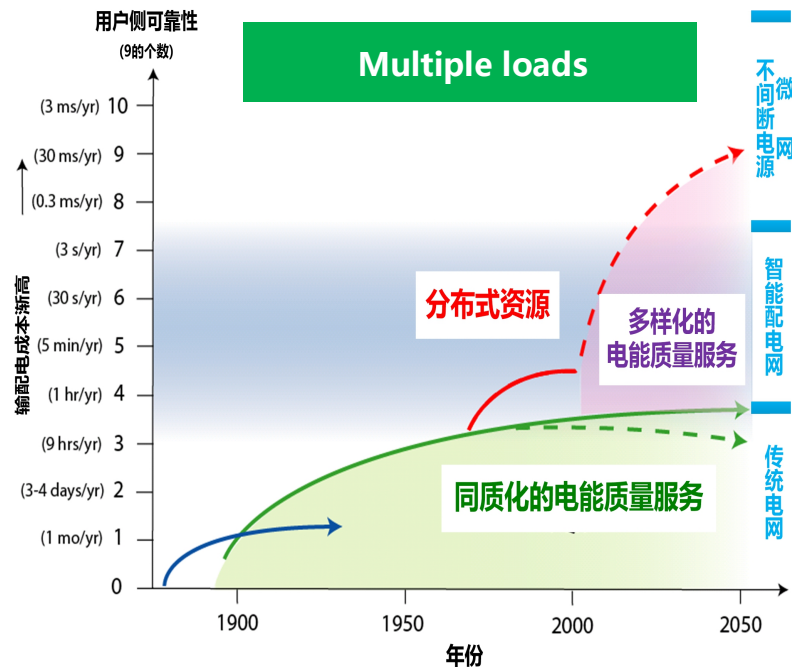
3.6 Development and construction mode(3)-

Customized power supply grid -- power quality and power supply reliability

Challenges

- Continuous growth of power load
- Resources and environment pressure
- Efficiency constraints of centralized generation
- Infrastructure interdependence
- High reliability cost
- Diversified power quality service demand

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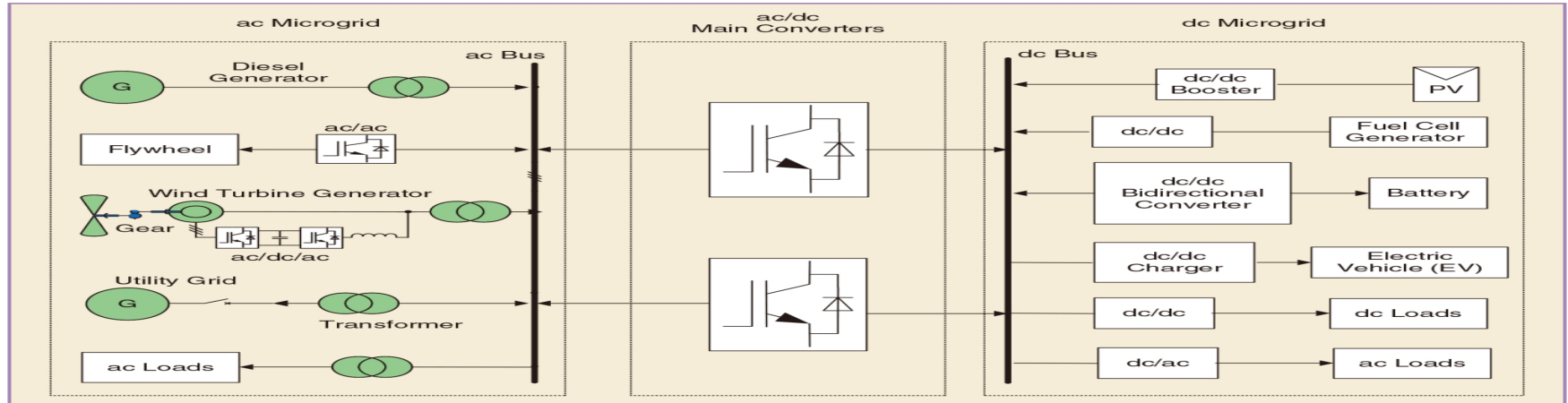


From Chris Marnay

3.6 Development and construction mode(4)-

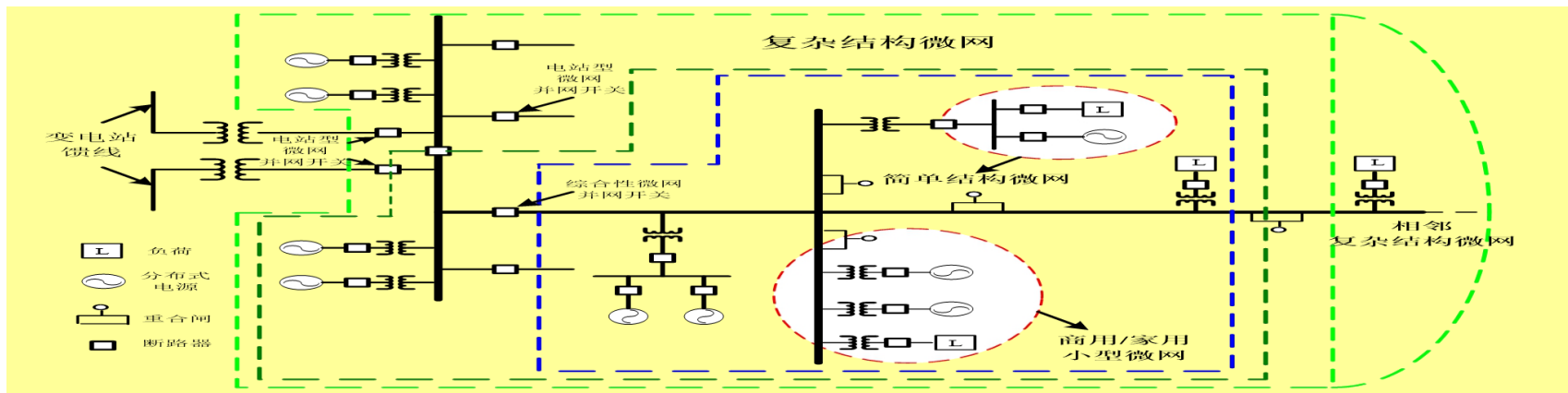
Customized power supply grid -- AC and DC hybrid power supply

- Power supply: Wind/Solar/Storage/Biomass/etc.
- Application scenario: data center, large public infrastructure, coexistence of AC and DC loads.
- Purpose: To realize direct power supply for AC/DC load and reduce system loss.



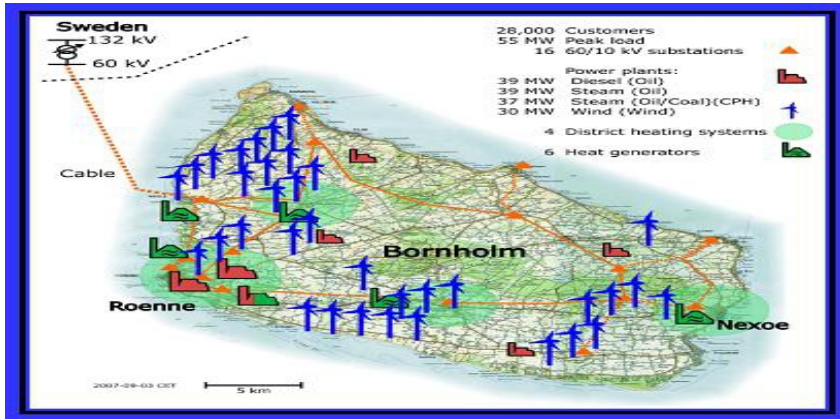
3.6 Development and construction mode(5)- Micro-grid of embedded distribution network (fault self-healing)

- **Power supply:** Wind/Solar/Storage/Biomass/etc.
- **Application scenario:** Part of the smart grid, owned by the grid company.
- **Purpose:** To realize the effective integrated management of microgrid power supply, realize the self-healing function of distribution network, and give full play to the advantages of microgrid.



3.6 Development and construction mode(6)- Independent micro grid, weak connection micro grid

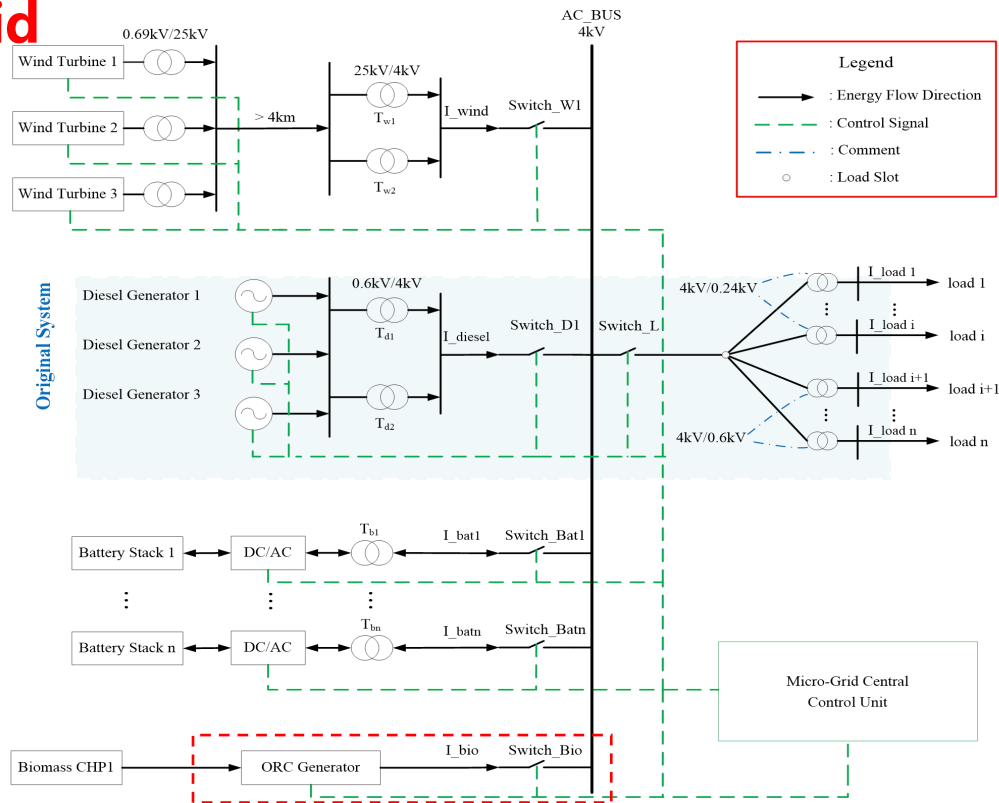
- Power supply: Wind/Solar/Storage/Diesel/Water/Biomass/etc.
- Application scenario: Remote and island areas.
- Purpose: To solve the problem of power supply in areas without electricity, renewable energy can replace (reduce) diesel power supply, and the power supply cost of conventional power grid is high and difficult.



3.7 independent micro-grid

Wind generator	1.5MW×3 sets
Diesel generator	1.1MW×3sets
Battery Storage	2.0MW×1h
Biomass	1.0MW×1sets

It is proposed to build an independent micro grid system of wind diesel storage biomass hybrid power generation to replace the original diesel generator set, make full use of local resources such as wind power and biomass, reduce environmental pollution and improve the system economy.

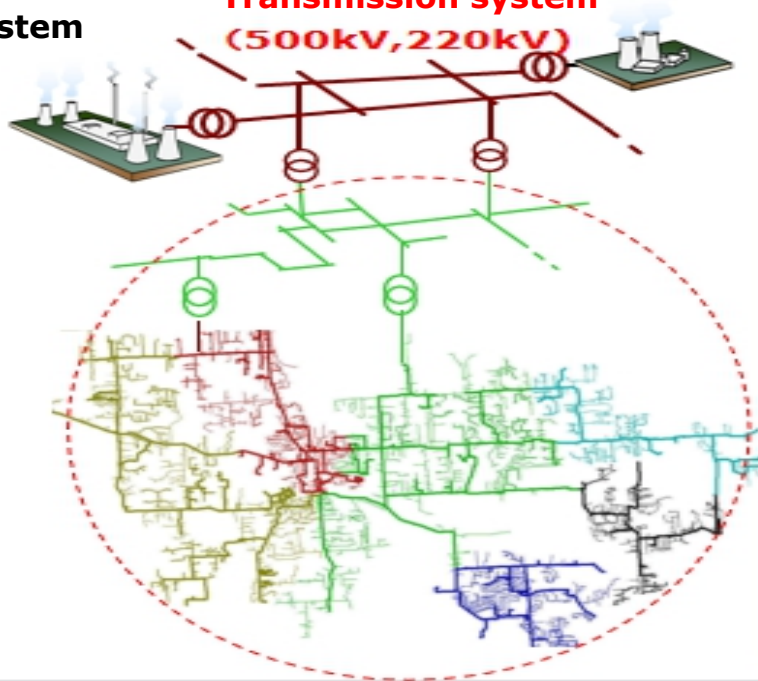


Wind/diesel/storage/biomass hybrid power generation independent micro-grid demonstration system

3.8 Structure of power system

Power generator
system

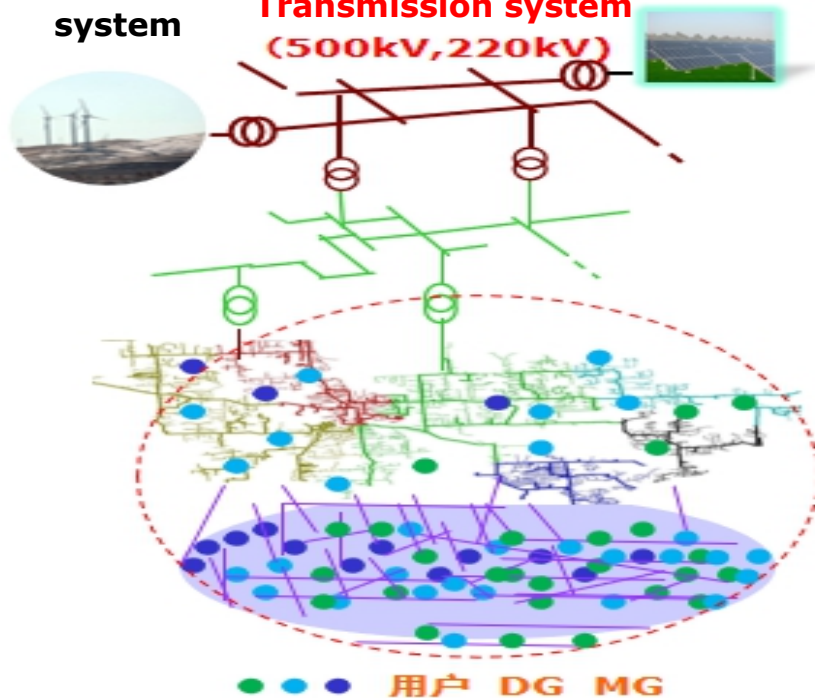
Transmission system
(500kV, 220kV)



NOW

Power generator
system

Transmission system
(500kV, 220kV)



Future

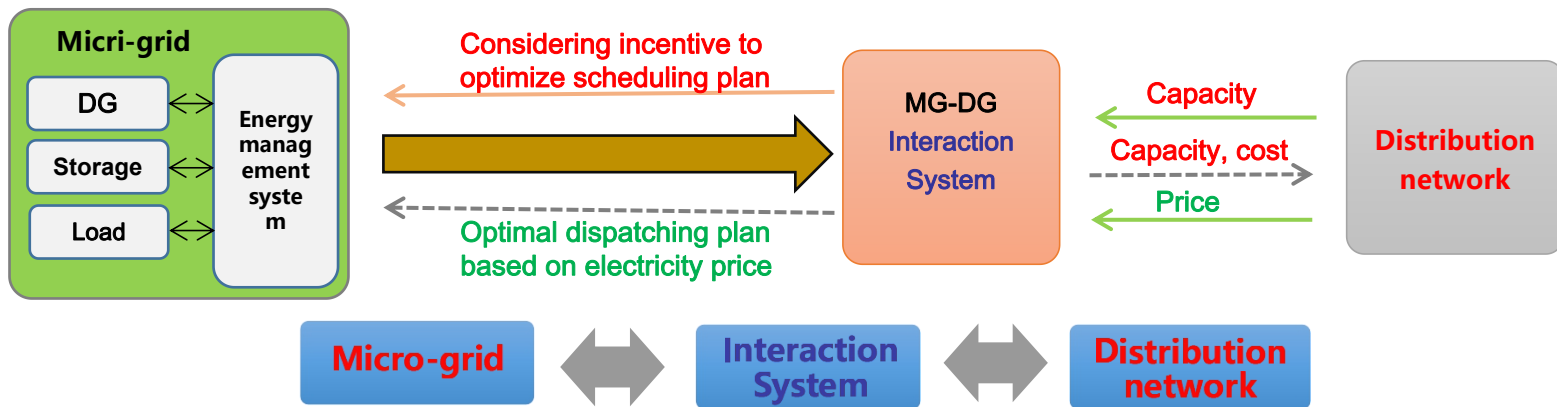
3.9 Micro-grid interaction mode and mechanism design

■ Electricity price based interaction between distribution network and microgrid:

According to the time-sharing electricity price mechanism of the distribution network, optimize the operation of the dispatching microgrid and respond to the electricity price policy.

■ Excitation based interaction between distribution network and microgrid:

The micro grid responds to the interactive demand of the distribution network, changes its own power consumption plan during the interactive period, participates in the interaction, and obtains certain interactive compensation.





4 Construction mode of Storage with renewable new energy

4.1 Necessity of energy storage system -- Background of current power supply system



Power Generator



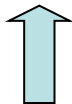
Power transmission,
transformation and distribution



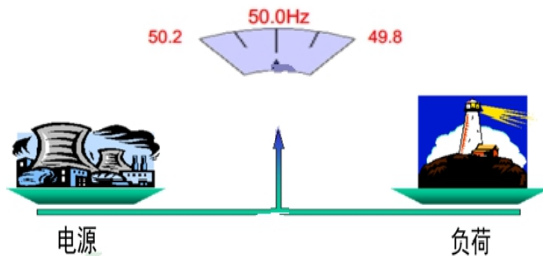
User

Characteristics of power system

- ◆ It is difficult to store electric energy on a large scale;
- ◆ Immediate transmission is required for generating electric energy;
- ◆ Generation/load real-time balance

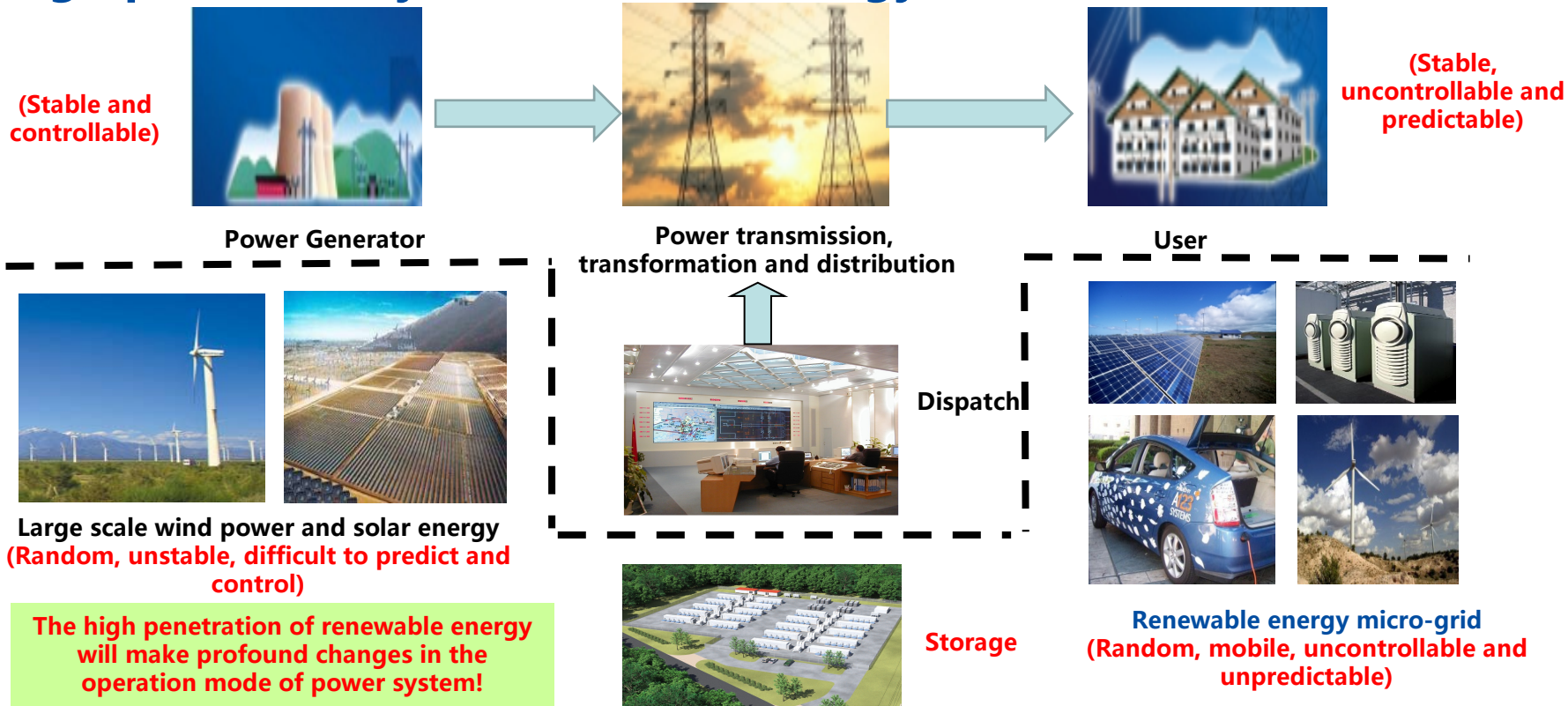


Dispatch



Power system: Rigidity (sufficiency, stability, real-time)

4.1 Necessity of energy storage system -- High permeability of renewable energy



4.2 Development and construction mode of energy storage and renewable energy

There are three main integration modes of energy storage and renewable new energy, namely power side energy storage, grid side energy storage and user side energy storage.

1、 Power side energy storage

Improve the grid connection characteristics of new energy and improve the grid assessment score

Reduce the waste of light and wind, and reduce the cost of system auxiliary services

Improve the overall efficiency of the new energy transmission system, improve the utilization rate of the transmission channel and the overall economy of the system;

2、 Energy storage at grid side

Improve power dispatching mode

Strengthen regional load adjustment and optimization

Promote coordinated and optimized operation of new energy and power grid

3、 User side energy storage

Expand the application mode of new energy terminals

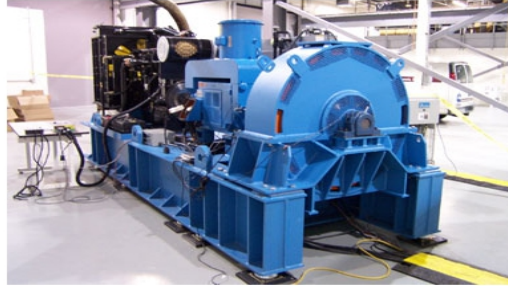
Increase the local consumption proportion of new energy

Save user expenses and reduce the dependence of load on power supply of large power grid

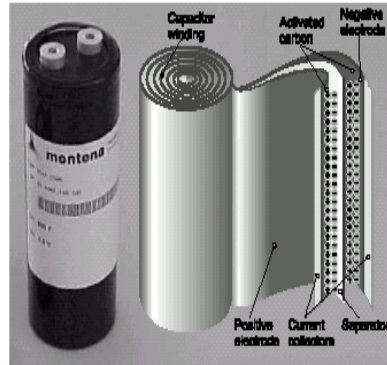
Improve the safe operation level of the whole power grid and the new energy consumption and utilization capacity.

4.3 Classification of energy storage system

There are three main types of energy storage systems, namely *mechanical energy storage*, *electromagnetic energy storage* and *electrochemical energy storage*.



Flywheel energy storage



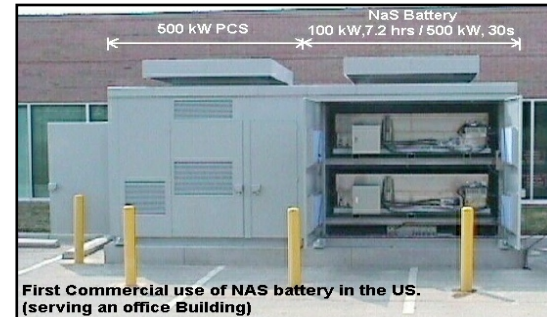
Supercapacitor



Lead acid battery



Compressed air energy storage

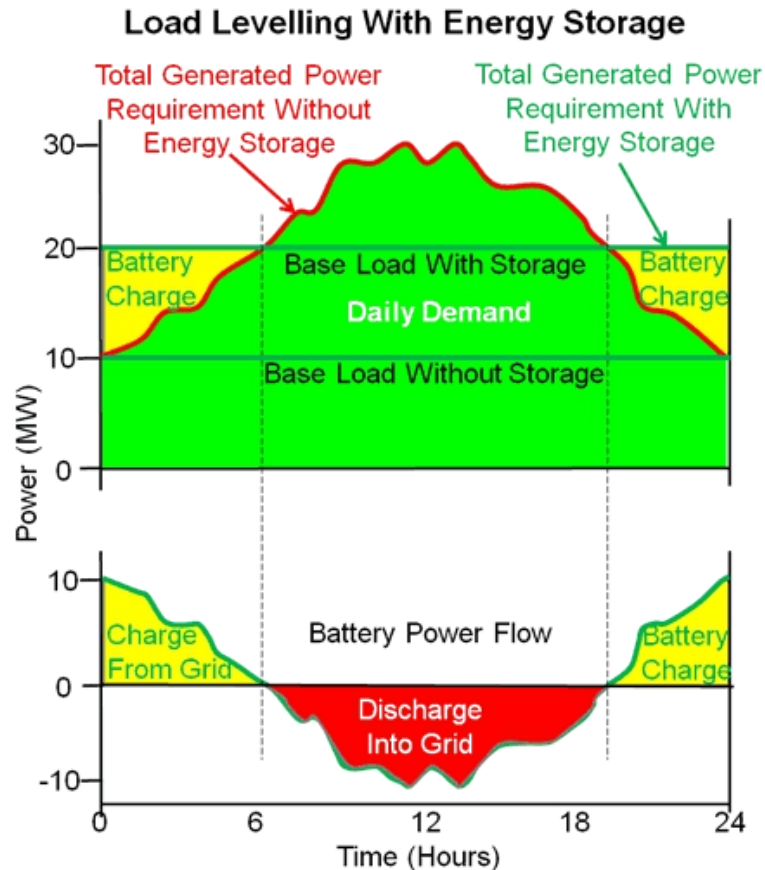


NaS Battery

4.4 Function of energy storage

(1) Smooth power curve

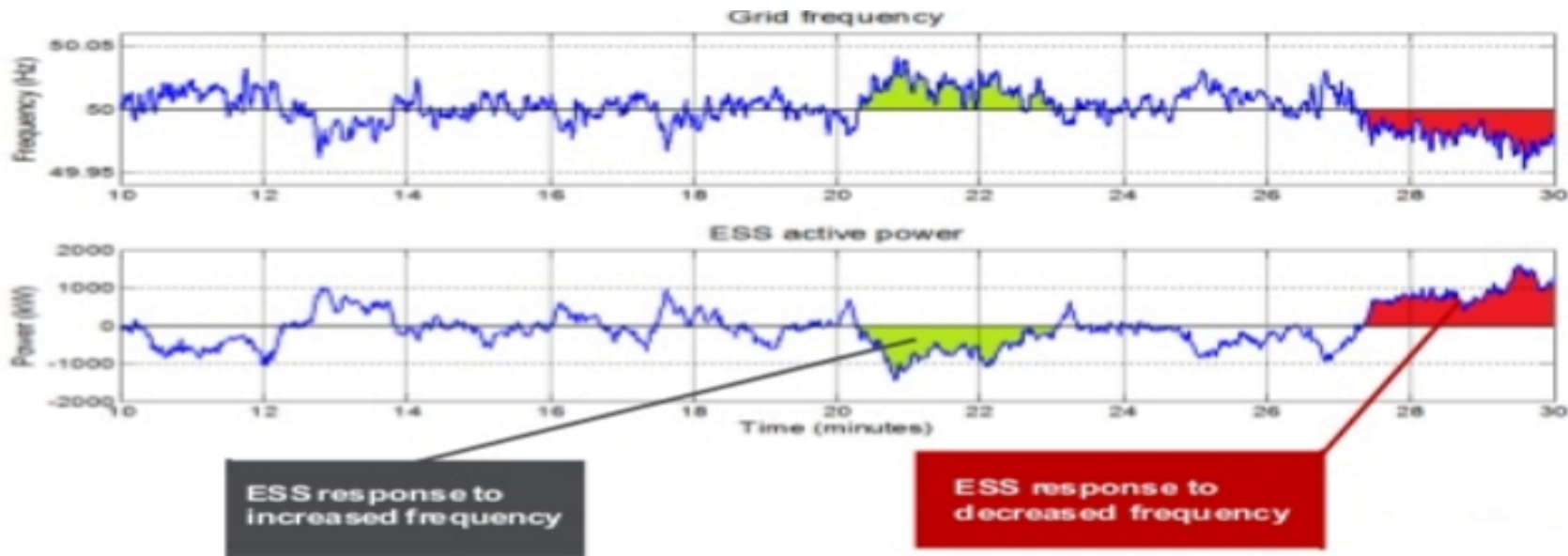
Utilizing the time and space transportation capacity of power/energy of large-scale battery energy storage power stations, layout the energy storage power stations, participate in peak shaving and peak clipping at the power generation side, can effectively smooth the comprehensive power curve of new energy, effectively alleviate the light and wind abandonment caused by the limited grid section at the peak, provide effective power supply support at the valley value, reduce the construction cost for capacity expansion of transmission channels and substations, and optimize the power generation characteristics of the whole network, Improve the utilization rate of power assets.



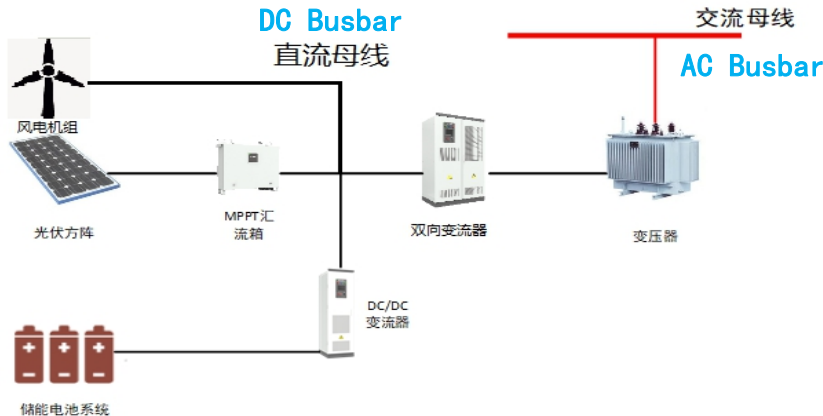
4.4 Function of energy storage

(2) frequency modulation(FM)

The energy storage system can replace some expensive frequency modulation units, realize the frequency modulation function, free the base load units forced to participate in frequency modulation, and improve the system efficiency.



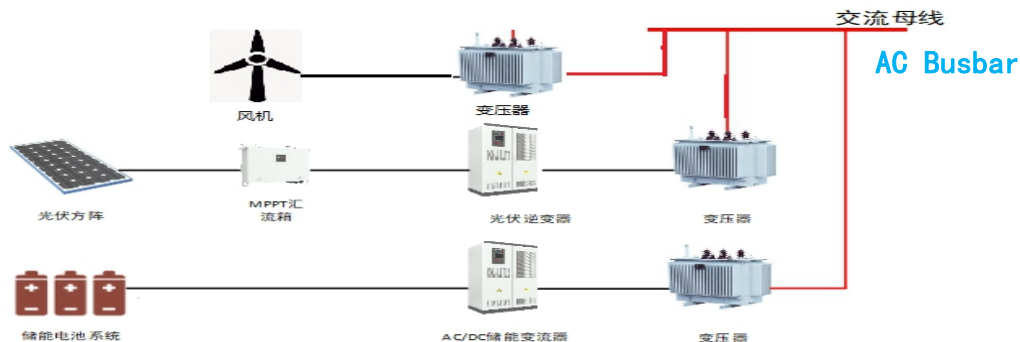
4.4 Energy storage system design scheme - wind solar storage/DC side coupling mode



Features of DC coupling:

1. The MPPT and energy storage transformation realize decoupling control, which does not affect the photovoltaic power generation, and the control is simple;
2. Less transformation links, high efficiency, high equipment utilization rate, and less one transformer;
3. Distributed energy storage. The failure of a single energy storage device will not affect the operation of large systems, which is conducive to the cascade utilization of batteries;
4. Place it locally, without increasing the floor area of photovoltaic power station

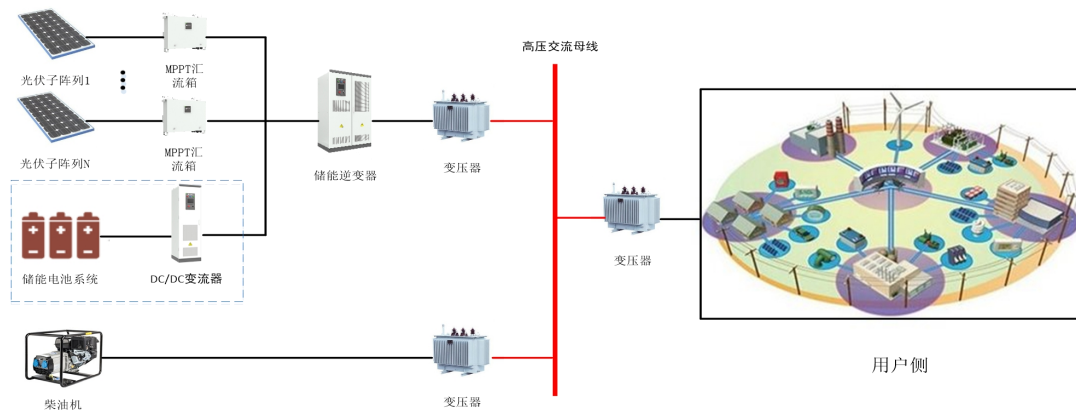
4.4 Energy storage system design scheme - Wind solar storage/AC side coupling mode



Features of AC coupling:

1. Applicable to large-scale wind, light and other new energy power stations;
2. Centralized management of AC side energy storage, with wide applicability;
3. It can realize the dispatching of multi energy power generation and enhance the flexibility of the power grid;
4. The AC bus side has strong scalability.

4.4 Energy storage system design scheme - Wind solar diesel storage/micro grid coupling mode



DC coupled small off grid (recommended):

1. Wind, light and energy storage DC side are coupled with high efficiency;
2. High power centralized bidirectional converter, fast system response, high stability, simple control, no need for complex EMS system;
3. It is suitable for MW level independent micro grid power stations, such as power shortage areas and infrastructure areas lacking large power grids. For example: Africa, islands, remote mountains



5 Typical cases

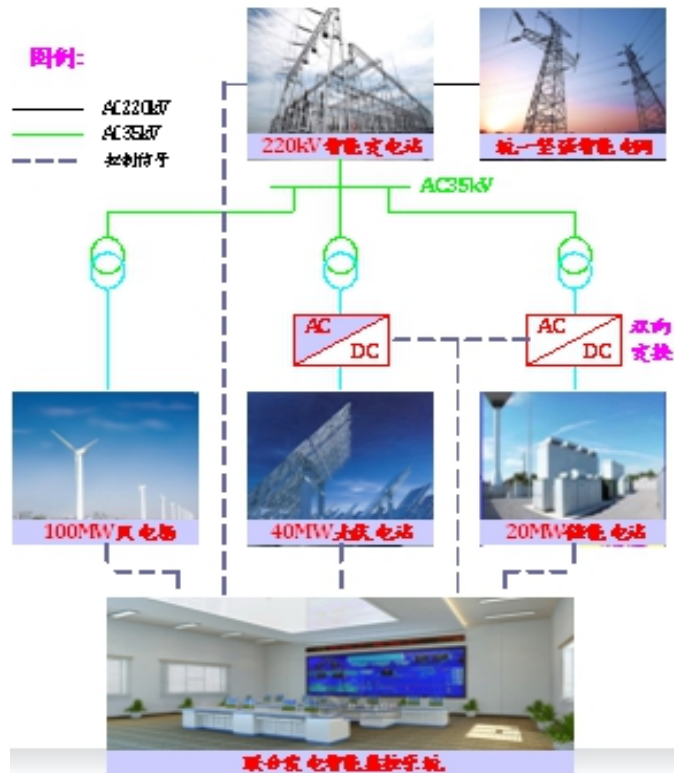
5.1 Case I: China Wind and Solar Energy Storage and Transmission Demonstration Project (Application of energy storage technology in power grid)

Due to the intermittence and randomness of wind and light energy, it is difficult for wind and light power supply systems to operate independently to provide continuous and stable energy output, which has become a key technical bottleneck restricting the large-scale development of renewable energy worldwide.

In order to study and solve the key technical problems in the fields of wind power generation, photovoltaic power generation, energy storage and smart grid in China, and lead the rapid and healthy development of clean energy industry, the State Grid Corporation of China (SGCC) built this project in Zhangjiakou.

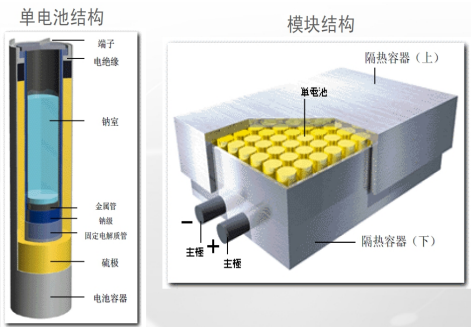
Including:

- Xiaodongliang Wind Farm 49MW;
- Mengjialiang Wind Farm 49MW;
- Dahe PV power station 40MW;
- Dahe energy storage device is 20MW.

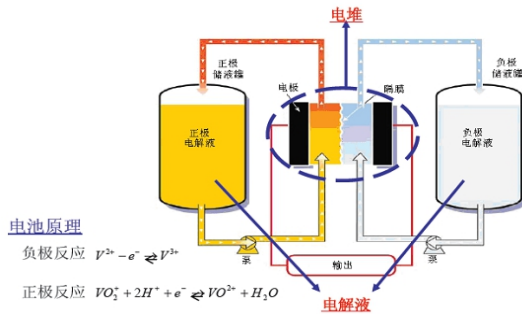


5.1 Case I: China Wind and Solar Energy Storage and Transmission Demonstration Project(Application of energy storage technology in power grid)

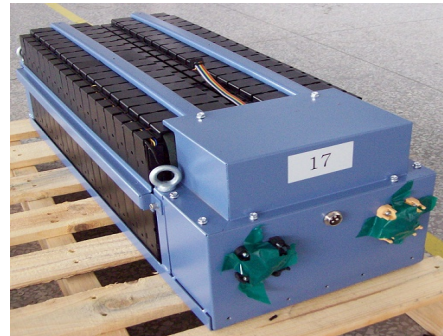
Considering the technical risk control, diversity of devices and the demonstration significance of the project, the combination of lithium battery, sodium sulfur battery and all vanadium flow battery is selected for the energy storage power station in this phase.



NaS Battery



Vanadium Redox Flow Battery (VRB)



Lithium iron phosphate Battery

5.2 Case 2: Shanghai Energy Source Network Load Storage Integration (Peixian County) Demonstration Base Project

Shanghai Energy Source Network Load Storage Integration (Peixian County) Demonstration Base Project -- In order to help clean energy in Jiangsu Province develop by leaps and bounds during the 14th Five Year Plan period, Datun Company, based on the national policy guidance and Jiangsu electric power development plan, combined with the current energy structure of Peixian County, Xuzhou City and the development foundation of renewable energy sources, and the natural advantages of grid structure and load volume in Peixian County, Actively build Datun's million kilowatt demonstration project of "integration of source, grid, load and storage", and strive to become a highlight project of Peibei New Energy Source Base.

Solar PV
460MW



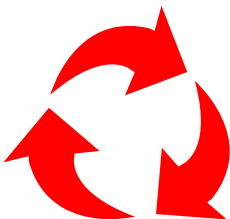
Electrochemical energy storage
138MW/276MWh



Coal fired power station
120MW



Compressed air energy storage
50MW/100MWh



江苏省发展和改革委员会文件

苏发改能源发〔2022〕966号

省发展改革委关于徐州大屯能源源网荷储一体化（沛县）项目实施方案的意见

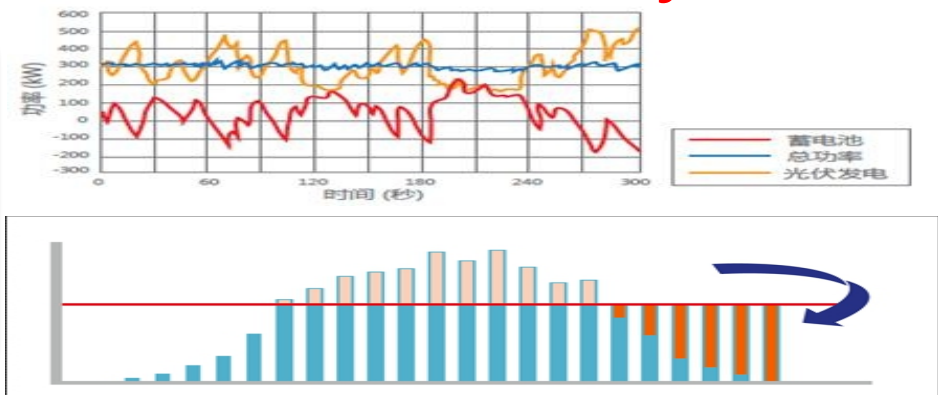
徐州市发展改革委：

你委《关于报送源网荷储一体化示范项目的请示》（徐发改能源〔2022〕142号）收悉。根据国家发展改革委《关于推进电力源网荷储一体化和多能互补发展的指导意见》（发改能源规〔2021〕280号）等文件要求，我委组织省能源规划研究中心、省电力公司等对报送的《上海能源源网荷储一体化（沛县）示范项目实施方案》（以下简称《方案》）进行了评估。现将省能源规划研究中心的评估意见转发给你们，并提出如下意见：

— 1 —

5.2 Case 2: Shanghai Energy Source Network Load Storage Integration (Peixian County) Demonstration Base Project

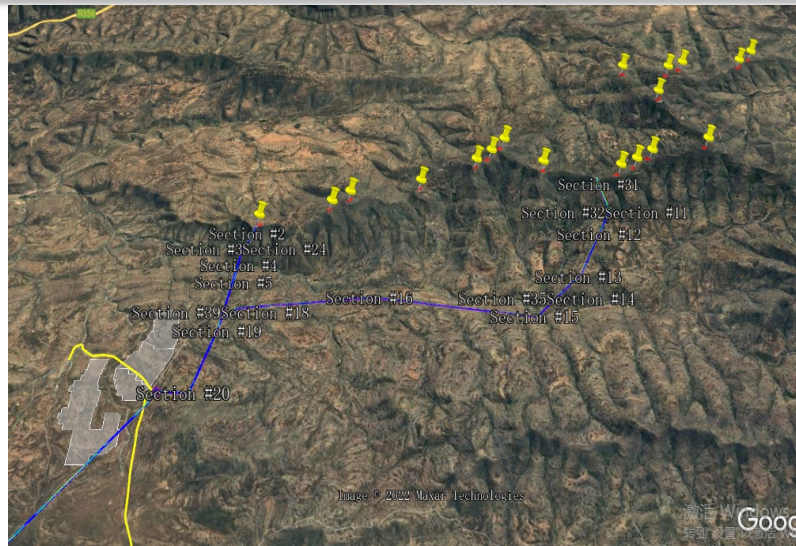
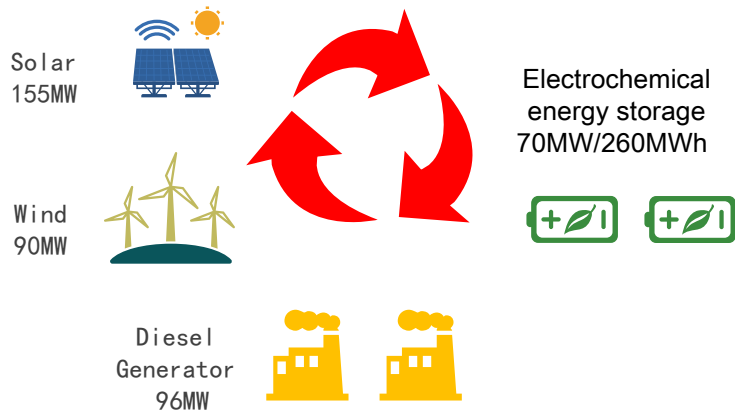
According to the requirements of the Review Principles for the Research Report on the Implementation Scheme of the Power Source Network Load Storage Integration and Multi energy Complementary Development Project: in principle, it does not occupy the peak shaving capacity of the system. At the same time, considering that the power consumption on the load side is expected to increase to 2.11 billion kWh in 2025. In 2025, the total power generation of new energy in the base will be 585 million kWh, with no new energy on grid.



Time	No.	Site Name	Capacity of wind or solar (MW)	Capacity of Energy storage (MW/MWh)	Generation of New energy (亿kWh)	Load consumption (亿kWh)	On-grid energy %
2021.1~2025.12	1	Shanghai energy 330MW Solar Power Station	330	99/198	5.85	21.1	0
	2	Zhuzai 130MW Solar Power Station	130	39/78			
		Total	550	82.5/165			
2026~2030	4	Xuzhuang Mining area 90MW Solar Power Station(Phase I)	90	27/54	14.27	31.2	0
	5	Yaoqiao Mining area 300MW Solar Power Station	300	90/180			
	6	Longgu 200MW Solar Power Station(Phase I)	200	10/20			
	7	Supporting Energy storage		50 /100			
合计			590	177 /354			
Total			1050	315/630			

5.3 Case 3: South Africa Oya Hybrid Facility Project

OYA Energy Hybrid Facility Project is being developed by G7 and Engie. The hybrid facility is currently in development and located in the Western Cape Province, South Africa. OYA Energy Hybrid Facility Project consist of the four types of generation facilities which will connect into the a 132/33kV substation, and subsequently connects to Eskom' s existing Kappa substation.



5.3 Case 3: South Africa Oya Hybrid Facility Project

OYA Energy Hybrid Facility Project consist of:

- 90MW of wind turbines (18 turbines),
- 155MWp of single axis tracker bifacial solar PV,
- 70MW/260MWh of Battery Energy System (BESS),
- 96MW diesel generators (62 sets of 1.54MW gen set are in normal operation, and 4 sets are redundant).

The collection station of this project is equipped with a set of cogeneration power plant control system (Cogeneration PPC) composed of wind power generation system, photovoltaic power generation system, energy storage battery system and diesel generator system.

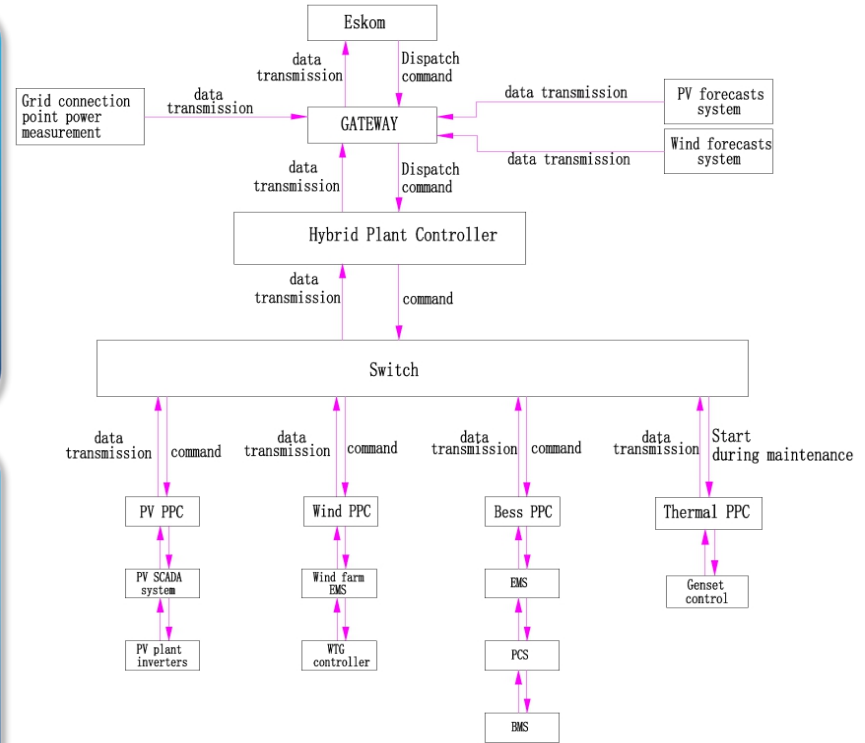


Figure Network topology of the cogeneration power control system

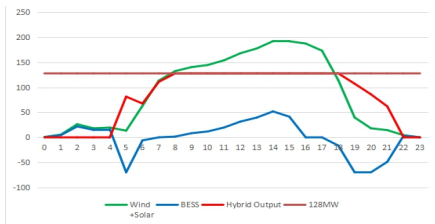
5.3 Case 3: South Africa Oya Hybrid Facility Project

PPA Requirement

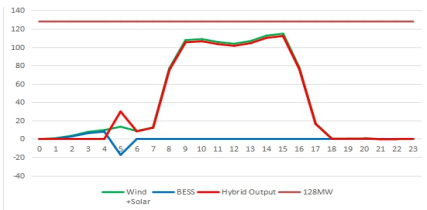
-Contract Period: 5:00 to 21:30

-Contract Capacity: 128MW

-Availability: 75%



Winter Period Typical Date Analysis



Summer Period Typical Date Analysis



Typical Date Analysis

Typical day analysis

8:00~16:00 Period

- Output is greater than 128MW.
- Charge BESS
- Peak clipping when beyond contract capacity.

16:00~21:30 and 5:00~8:00 Period

- Output is less than 128MW.
- Discharge from BESS to Hybrid system

21:30~5:00 Period

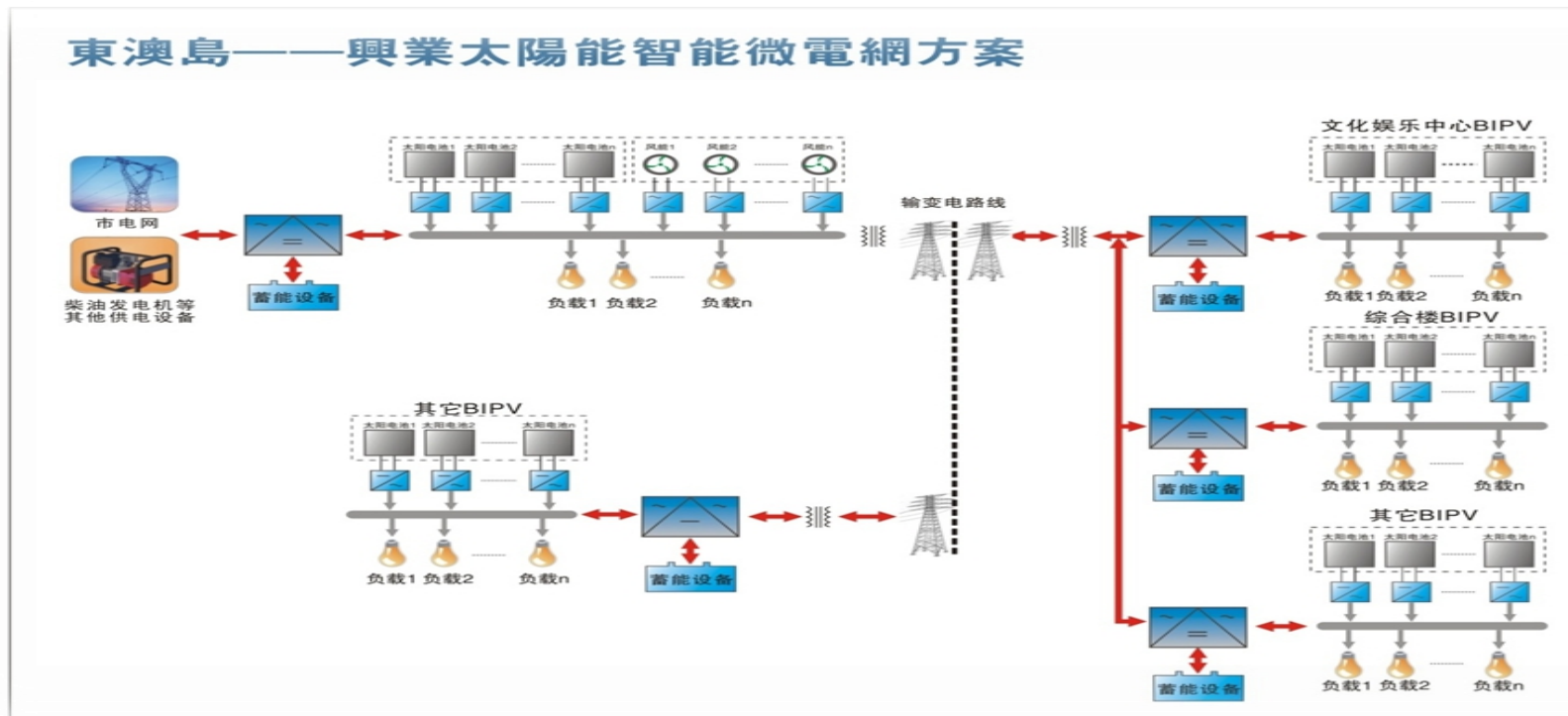
- Charging BESS

5.4 Case 4: Zhuhai Dong'ao Island micro-grid - Island smart micro-grid

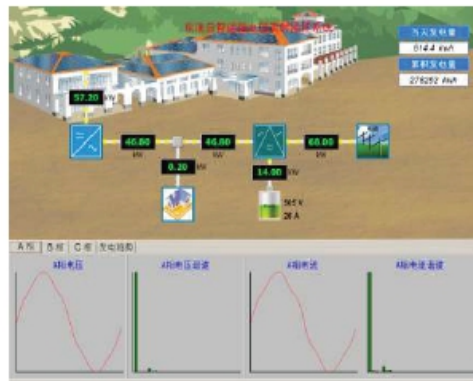
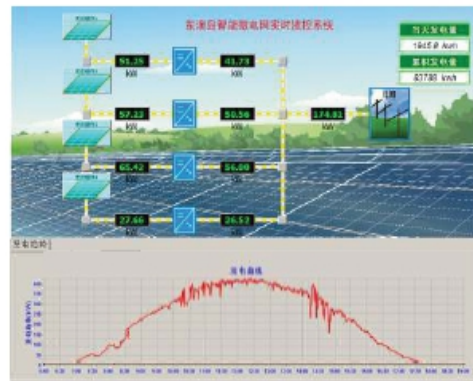
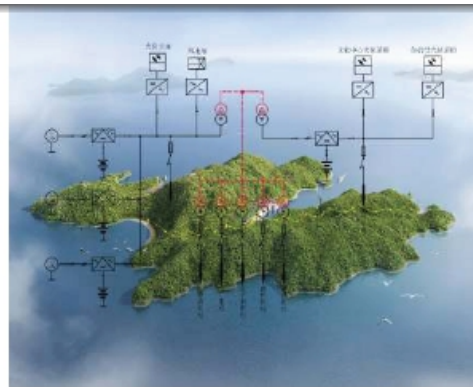
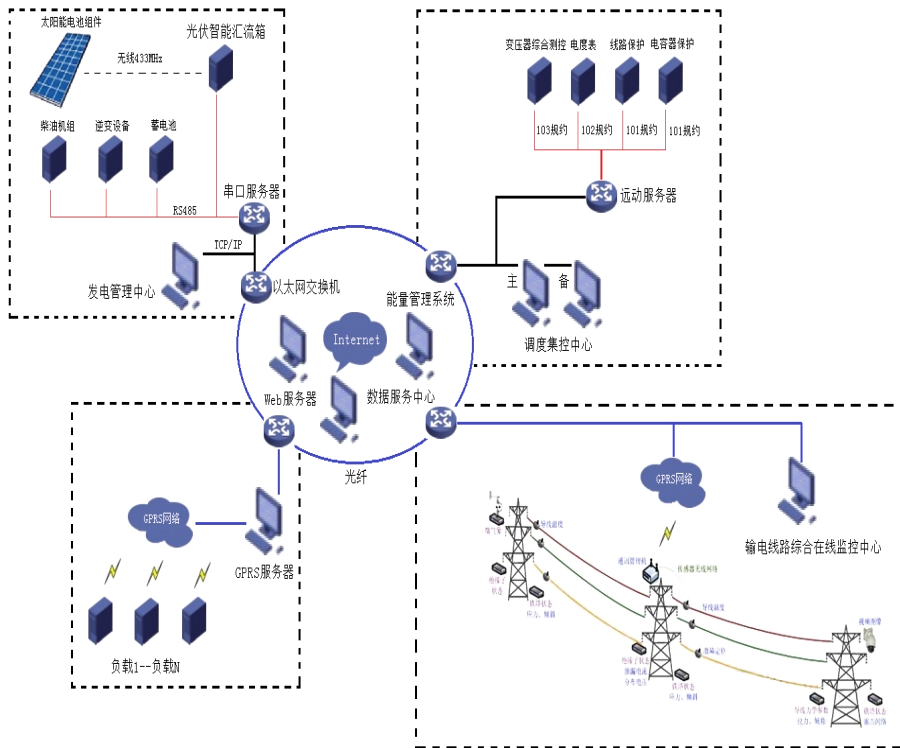


Wind 45kW + Solar 650kWp + Battery Storage 2000kWh+ DG 1220kW = Wind/Solar/Storage/Diesel Power Supply System

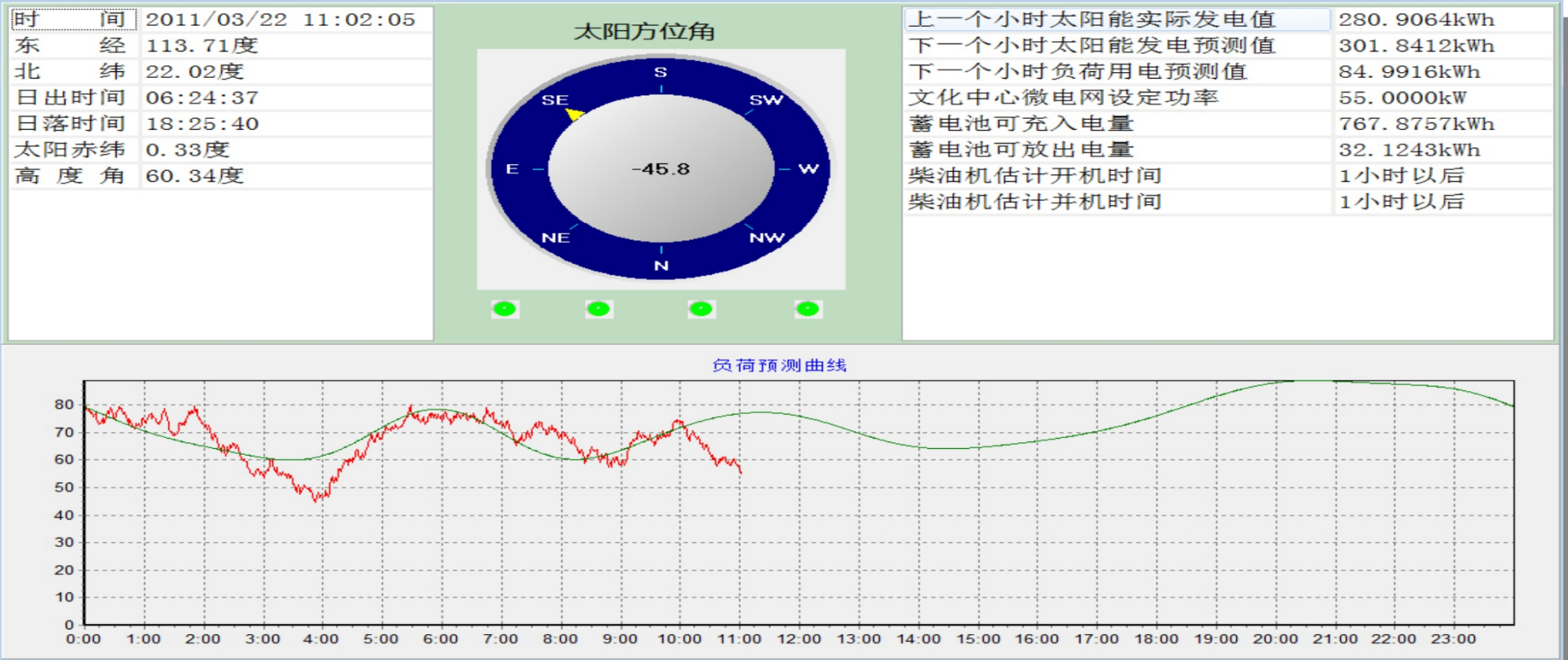
5.4 Case 4: Application of energy storage technology in micro-grid - Zhuhai Dong'ao Island micro grid - Smart grid scheme



5.4 Case 4: Zhuhai Dong'ao Island Microgrid - Data Acquisition and Monitoring System



5.4 Case 4: Zhuhai Dong'ao Island Microgrid - Power Load Forecast

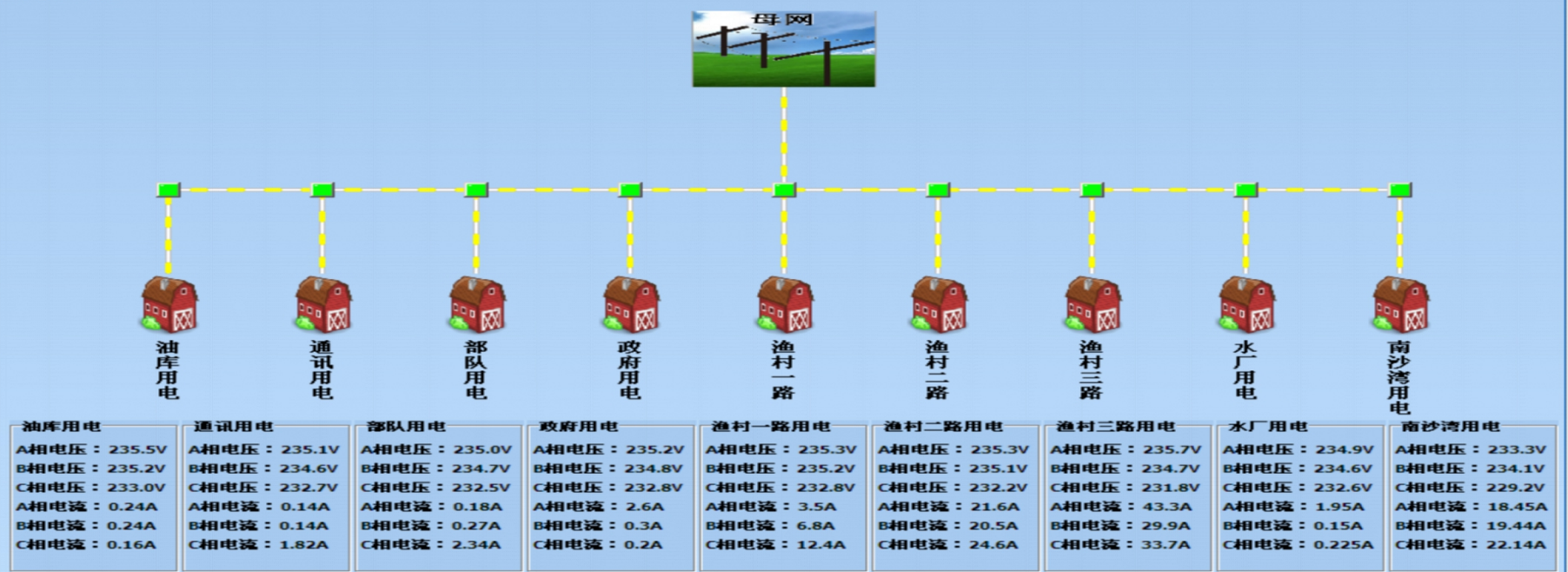


负荷预测曲线



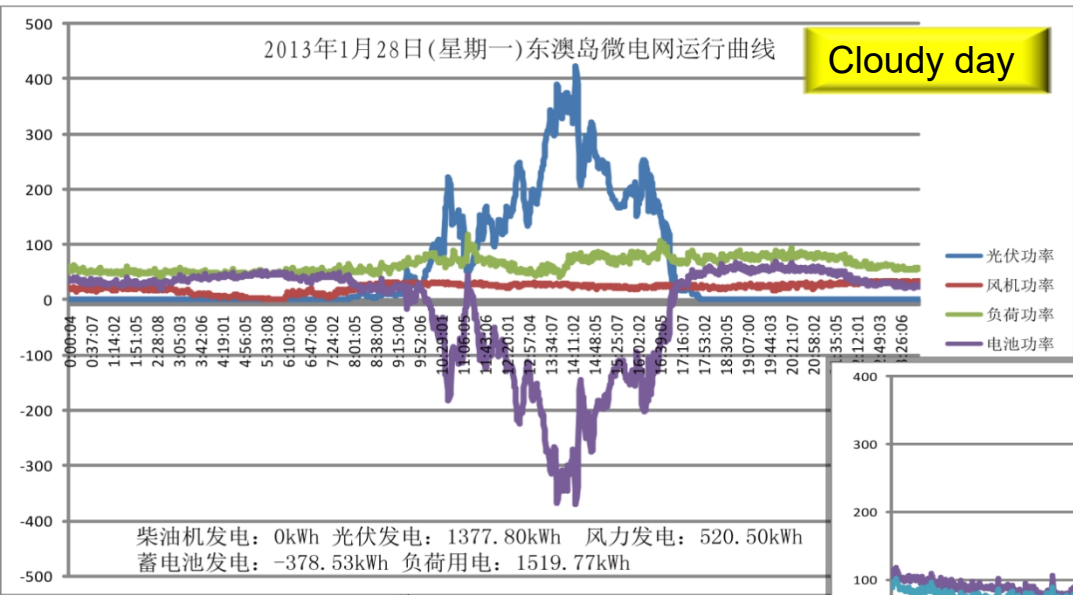
5.4 Case 4: Zhuhai Dong'ao Island Microgrid - Monitoring and Management of Power Load Measurement

负载监测



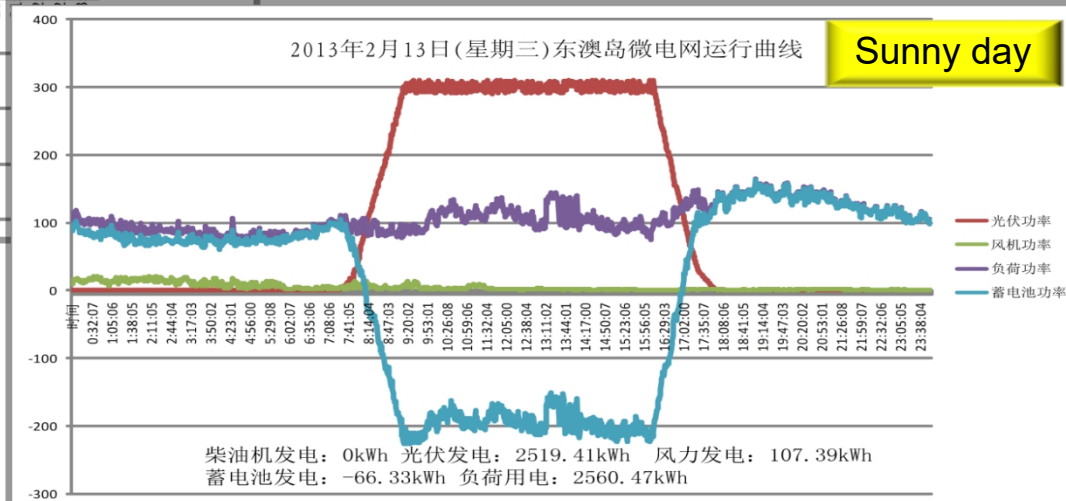
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5.4 Case 4: Zhuhai Dong'ao Island Microgrid Power Supply Effect



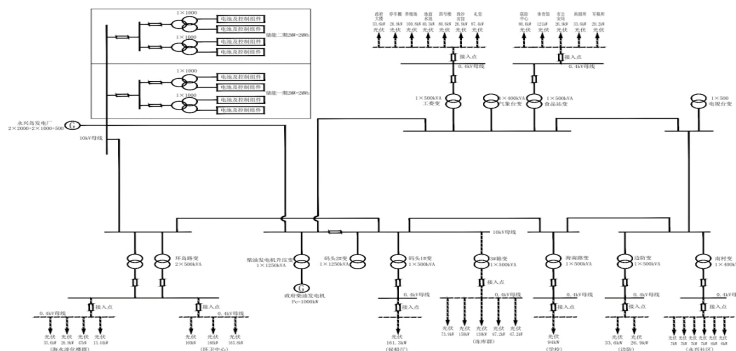
From the curve of solar power generation, even in cloudy days, solar power generation can basically meet the load demand of the whole day.

Microgrid energy control: power limiting operation; After the microgrid control is changed to power limiting operation, the change trend of solar power generation curve and solar radiation is completely different.



5.5 Case 5: "Internet plus" Smart Energy Demonstration Project in Yongxing Island, Sansha City, Hainan Province

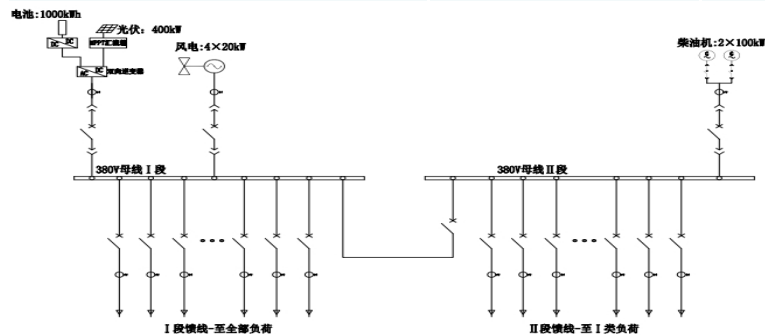
The project is composed of distributed photovoltaic power generation, diesel power generation, energy storage power supply, power distribution network, seawater desalination equipment, controllable ice, intelligent charging pile and other loads to build the island wide energy internet, realize the interconnection of the island wide energy data, and also form the island wide smart micro grid. The distributed roof photovoltaic installed capacity of Phase I project is 2.1MW, which is mainly arranged in civil areas. The installed capacity of energy storage power is 2MW, with a capacity of 2MWh. The diesel generator assembly is 4MW. The distributed roof photovoltaic installed capacity of Phase II project is 2MW, with a capacity of 2MWh.



5.5 Case 5: "Internet plus" Smart Energy Demonstration Project in Yongxing Island, Sansha City, Hainan Province

There are 5 engineering projects in this project. The power supply of each project is a small off grid project composed of wind, light, diesel and storage.

Project	Solar	Wind	Diesel	Battery Storage
No.1	400kW	4x20kW	2x100kW	1000kWh
No.2	250kW	3x20kW	100kW	500kWh
No.3	150kW	2x20kW	100 kW	400kWh
No.4	50kW		100kW	150kWh
No.5	150kW		100kW	200kWh





中国电建集团中南勘测设计研究院有限公司
ZHONGNAN ENGINEERING CORPORATION LIMITED

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