Design and application of smart-microgrid in industrial park

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Abstract. Due to the uncertain and randomness of both wind power photovoltaic output of power generation side and charging load of user side, a set of wind-solar-storage-charging multi-energy complementary smart microgrid system in the park is designed. Through AC-DC coupled, green energy, such as wind energy, distributed photovoltaic power and battery echelon utilization energy storage power, can be supplemented as factory power. While alleviating the power consumption pressure in the plant, it also realizes functions such as smoothing the fluctuation green energy power generation, and peak loading shifting. Vehicle DC super and fast charging are also integrated in this station. The system realizes real-time state monitoring of different energy sources, energy storage, power distribution, and loads, which can guarantee green, smooth, efficient and economic operation of the multi-energy complementary system in the plant.

Keywords: Wind-solar-storage-charging system, Multi-energy complementary, Battery echelon utilization, Microgrid, Energy storage.

1 Introduction

In 2021, carbon dioxide emissions from energy consumption accounts for about 88% of total emissions, while the power industry accounts for about 42.5% of the total carbon dioxide emissions. So, the power industry will directly affect the progress of emission peak and carbon neutrality. The construction of a new power system is expected to drive the transformation of the whole electric power system.

According to State Grid's plan for the new power system, as shown in Figure 1, the power supply side will be transformed from traditional energy as the main power source to a new energy-based, multi-energy complementary energy structure. The grid side will build a flexible grid and smart, digital system, increase the proportion of terminal electrification and comprehensive energy service mode on the user side, to build a new power system integrating source, network, load and storage at multiple levels.

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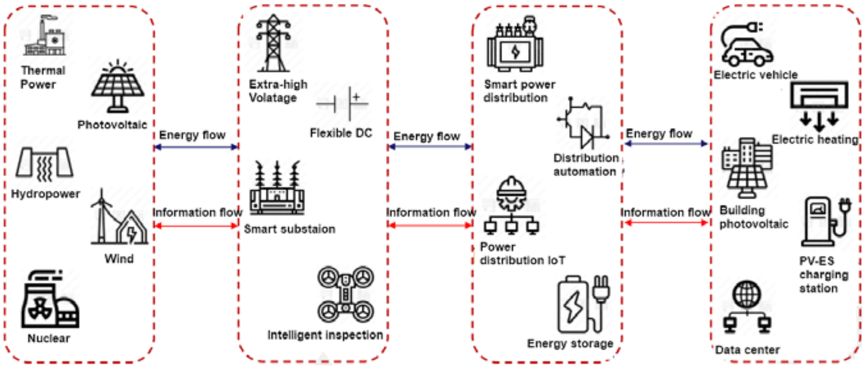

Fig. 1. Schematic diagram of new electric power system.

On the other hand, according to China Association of Automobile Manufactures, in 2021 the sales of new energy vehicles reach 3.52 million and the market penetration rate is also close to 20%. It is predicted the total amount will be over 10 million units in year 2025. With the rapid increase in the number of new energy vehicles, the electric vehicle charging station model that relies on traditional grid thermal power supply has an excessive impact on the distribution network. Meanwhile, industrial and commercial enterprises are faced with the "dual control" target of total energy consumption. The utilization of distributed clean energy has become an effective means for enterprises to reduce total energy consumption and achieve green energy consumption.

The battery retired from electric vehicle is used as a mobile energy storage system. After reaching a certain scale effect, it can be a highly available resource for the power grid to participate in the electricity market [1]. Therefore, combining renewable wind and solar energy resources with electric vehicle charging stations to establish a set of scenery storage and charging integrated charging stations has become a new development and research direction for vehicle charging stations [2]. The microgrid composed of the integrated system of wind-PV-ES and charging can not only realize the grid-connected operation with the large grid, but also disconnect and switch to the independent operation mode during the detection of the fault of the large grid. The use of distributed renewable energy in microgrids can effectively reduce carbon emissions and promote energy recycling [3].

Fig. 2. Tesla PV-ES station in Shanghai.

At present, there are many mature cases of the concept and projects of Photovoltaic and Energy Storage (PV-ES) stations. For example, in July 2021, Tesla completed the PV-ES and integrated super charging station in Shanghai. After the charging station generates electricity through the solar roof system, the electric energy is stored in the energy storage system, it can finally be used for daily charging of some electric vehicles. In recent years, State Grid has vigorously built smart wind-PV-ES charging stations in Hubei, Shanghai, Qinghai. Besides Tesla and State Grid, domestic companies, such as CATL, NIO, etc., are also involved in this industrial chain.

In this paper, combined with the actual energy demand in the factory area and the green travel needs of employees, a set of wind-solar-storage-charging microgrid energy charging station is designed. The combination of AC-DC coupled microgrid technology and cloud communication technology, are used to realize the coordinated operation of clean energy and demand-side controllable loads.

2 System design

2.1 System design

The charging station is placed in the production plant, parking area. A typical wind-solar-storage-charging system includes wind power generation, photovoltaic power generation, energy storage, and related loads, which are connected to AC-bus to realize grid connection [4]. In this project, fast DC charging pile, utilization of retired vehicle batteries are also planned.

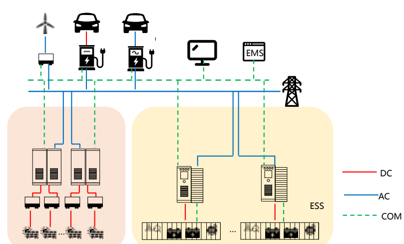

Fig. 3. System topology.

This project is a multi-energy microgrid project, including 1kW wind power, 30kW photovoltaic, 500kW/1000kWh battery echelon utilization energy storage and charging system.

The charging pile is a company self-developed product. In this project, 360kW peak power super charging piles and 22kW AC charging piles are arranged. The energy management system and platform of the whole station realize the functions of information collection and control of various devices in the micro-grid, and upload the information to the cloud platform at the same time.

2.2 ES energy storage design

2.2.1 Overall technical solution

The technical scheme of the 1MWh energy storage system is equipped with 2 sets of 250kW/500kWh energy storage units, placed in a 20-foot container, mainly including 2 sets of 250kW energy storage converter systems and 500kWh energy storage battery systems.

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Table 1. 250kW/500kWh energy storage.

No.	Components	Name	Techncial parameter
1	Battery	Capacity	2×500kWh
2	PCS	Power	2×250kW
3		Volatage	AC 400V

The energy storage system is shown as Figure 3.

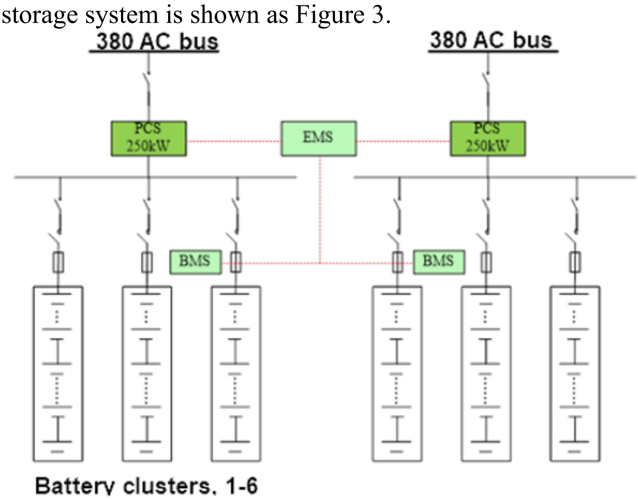

Fig. 4. 250kW/1000kWh energy storage system.

The energy storage system adopts electrochemical energy storage technology, which consists of an integrated package of electric cells in series-parallel form. The battery of the energy storage system is a lithium iron phosphate battery. Under the condition of 25℃, 0.5C charge/0.5C discharge, the 90% DOD cycle life of the battery system will above 2400 times, and the end life capacity will be above 70%.

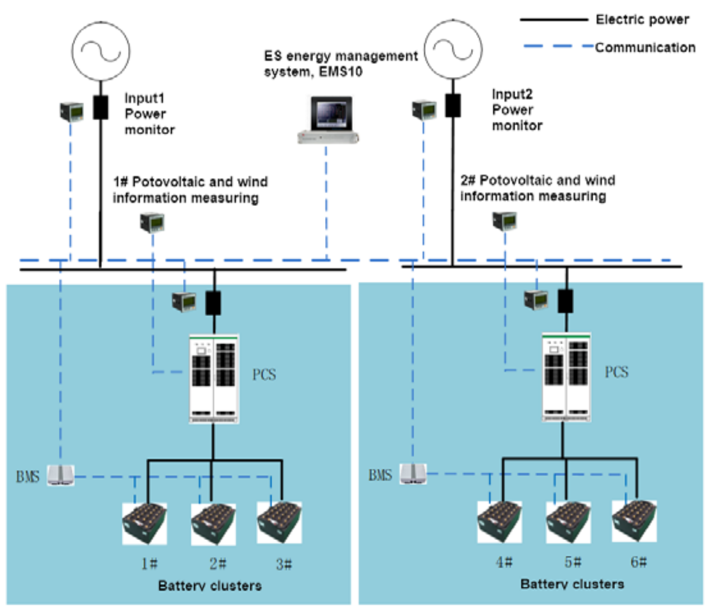

Fig. 5. Energy storage architecture.

2.2.2 Energy management system

The energy storage system is equipped with an EMS monitoring system, which is mainly responsible for energy management and protection strategies. In this project, photovoltaic, charging and wind power information are collected via CAN, RS485 and Ethernet, the charging and discharging power of the energy storage power station is adjusted in real time to realize the optimal dispatch of energy, which mainly includes functions such as dynamic capacity expansion and overload prevention. The whole EMS is shown in Figure 4.

The EMS has whole battery management functions, which can realize real-time monitoring of the operation information of the energy storage system, including information collection, real-time monitoring of battery cells, battery modules, battery clusters, and battery stacks in the energy storage power station, with functions monitoring, optimization management, smart maintenance, etc.

2.2.3 Battery system

This project uses a lithium phosphate battery, and the technical parameters of the battery are shown in Table 2:

Table 2. Battery cell parameters.

No.	Item	Technical parameters	
1	Cell	lithium phosphate, LFP	
2	Capacity	142Ah	
3	Nominal voltage	3.2V	
4	Max charing voltage	3.65V	
5	Discharing voltage	2.5V	
6	Cell charging current	0.5C	
7	Cell discharging current	1C	
8	Max pulse discharge current	240A,≤3 min	
9	Self-discharge rate	≤3%, per month	
10	Cell resistance	≤0.50mΩ（50%SOC,1000Hz）	
11	Cell weight	2.62kg	
12	Working temperature	Charging	-10℃～55℃
		Discharging	-30℃ ～55℃
		Storage	-40℃ ～60℃

The battery module is composed of 32 single cells with the specifications of 2P16S, 14.54kWh and nominal voltage of 38.4V. The battery module is equipped with the acquisition module BMU of the BMS, which is used for the measuring parameters such as voltage and temperature of the module, and cell balance, fan control.

The battery cluster includes 13 battery modules and a high-voltage junction box, with a capacity of 2P206S, 189.03kWh and a nominal voltage of 665.6V. The technical parameters table of the battery cluster are as follows:

2.2.4 Battery management system

The BMS adopts a three-layer architecture, in which the battery management module (BMU) detects information such as voltage and temperature of each string of batteries, and each cluster of batteries contains 13 BMUs. And 1 BCMU used for communication with BMUs, and uploads information to battery cluster maangement system (BAMS). BAMS receives the

BCMU information and communicates with the energy storage PCS. The whole architecture is shown in Figure 5.

Table 3. Battery cluster parameter.

No.	Item	Techncial parameters	Comments
1	Capacity	284Ah	
2	Nominal voltage	665.6V	
3	Working voltage	582.4V～759.2V	
4	Consist charging	0.5C@25℃	
5	Consist discharging	0.5C@25℃	
6	Weight	≈2000KG	
7	Energy	189.03kWh	
8	Isolation	Isolation resistance≥500MΩ(1000VDC)	
9	Pressure resistance	2830VDC, leakage current＜20mA	50% start
10	Cell max charing voltage	3.65V	
11	Cell max discharging voltage	2.8V	

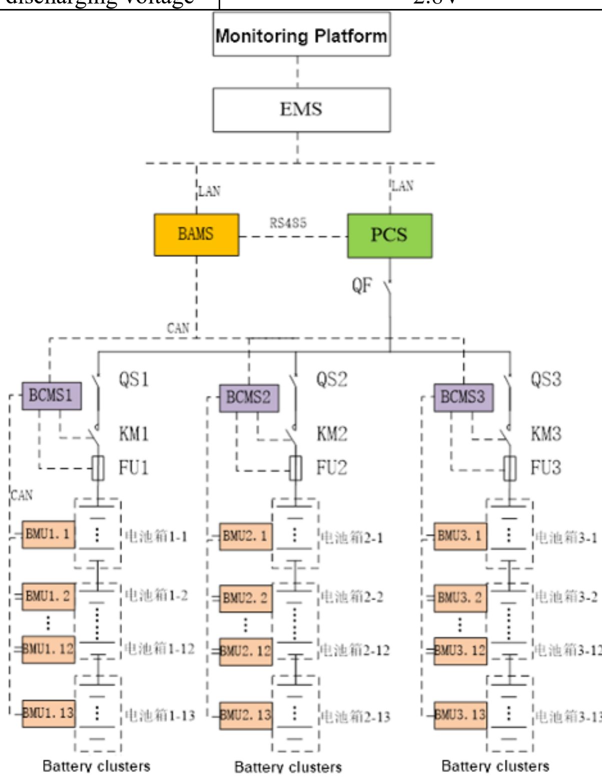

Fig. 6. BMS architecture.

2.2.5 Container arrangement

The main purpose of the container is to organically integrate energy storage batteries, communication monitoring and other equipment into a standard unit, which has its own independent power supply system, temperature control system, heat insulation system, flame retardant system, fire alarm system, electrical interlocking system, safety escape system, fire protection system and other automatic control and safety guarantee systems.

2.3 Station energy management

The main functions of energy management include information collection, orderly regulation of devices in the microgrid, uploading information to the cloud platform, and realizing the orderly and stable operation of devices in the micro-network, as shown in Figure 7.

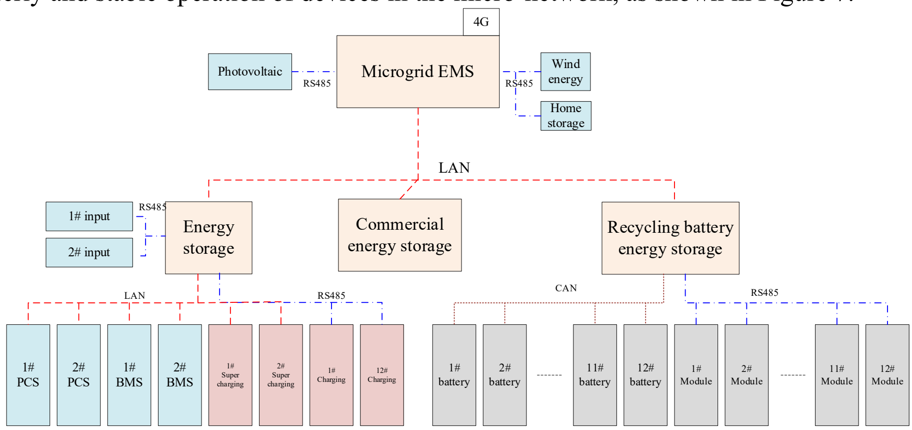

Fig. 7. Recycling batteries used for energy storage.

2.4.1 Cloud platform monitoring

The cloud platform is used to monitor following information:

a. Monitor the system operation in real time;
b. Graphic monitoring screen includes: energy storage overview information, main wiring diagram, energy storage unit PCS monitoring, energy storage unit battery group monitoring, battery operation information monitoring, communication conditions, display indicators, recent electricity consumption curve, data statistical reports, data import and export;
c. The graphic monitoring screen form should include: date and time represented by text or icons, analog value, remote signal status value, power value, real-time statistical value, historical data, calculated value, etc.
d. The objects of control operation should include: DC switch, startup and exit of main equipment, etc.;
e. The adjustment objects include: energy storage PCS power setting, device operating parameter setting, etc.;

Fig. 8. Cloud platform monitoring.

2.4.2 Control strategy

In order to reduce the abandonment of wind power and PV and load, while taking into account the peak and valley costs of electricity. The following overall system control strategy is developed.[5][6][7]. According to the peak and valley time period of the plant, the control strategy of 2 times charging and 2 times discharging is implemented every day, also the charging demand is considered, to prevent grid overloaded.

2.5 Peak cut strategy

According to the peak and valley time period where the project is located, the constant power and fixed time period peak shaving and valley filling control strategy is implemented. Peak period: 19:00-21:00, a total of 2 hours; during this time period, the energy storage is discharged at full power, 500kW;

Peak hours:

09:00 - 11:00, in this time period, the energy storage is discharged at full power, that is, 500kW;

11:00 - 13:00, the energy storage is charged at full power during this time period, 500kW;

15:00 - 19:00, the energy storage is discharged at full power during this time period, 500kW;

22:00 - 08:00, the energy storage is charged at a constant power, and the charging power is tentatively set at 50kW.

System is standby in other using periods.

2.6 Over load preventing

1) The energy storage has 2 times charging periods. According to the charging demand and new energy demand, it is ensured that 2 AC buses cannot be overloaded;

2) While the discharging periods, considering that the maximum power of each bus, it can meet the full power operation of one supercharged pile; The capacity is reserved (30% to 40%) to prevent the overload of the busbar caused by the charging of the energy storage and the charging of the electric vehicle at the next moment.

3) While the system charging periods, 2 AC buses should not be overloaded.

Remarks: Small wind power and photovoltaic power can be fully consumed, and only data monitoring is performed.

2.7 Off-grid operation strategy

1) When the maintenance or power outage occurs, the energy storage is used as the main power to ensure the power supply of important loads.

2) At this time, it is necessary to stop the energy storage, set the energy storage to the off-grid operation mode, and disconnect the main incoming line switch of the power station at the same time, leaving only the bus where the important load is located. At the same time, the load power is required to be less than the rated power of the energy storage. In the energy storage PCS, set the control mode to off-grid operation mode;

3) Select off-grid mode.

4) After returning to the homepage, click Power On to enter the off-grid operation mode. Complete the backup power setting.

5) After the inspection is over, restore all settings and change the mode selection to grid connection.

3 Implementation and station operation

The energy storage system currently has 2MWh. Due to the existence of the energy storage system, there is no impact on electric power grid while super charging piles using. In the actual use process, considering 50% of the energy storage system capacity reservation, 10-15 vehicles can be charged at the same time. Referring to the local lighting data in Ningbo, this project can achieve a daily photovoltaic power generation of more than 120kWh, which can meet 2-4 electric vehicles charging.

Fig. 9. Actual operation at night.

In the actual use process, the system can reduce the power capacity occupancy rate, cope with the insufficient power capacity during the charging concentration period, and use energy storage as a supplement to the power capacity. At the same time, it can also be used as a disaster backup power supply in the factory area to cope with the power consumption after sudden power outages such as typhoons and rainstorms.

4 Summary

In this paper, a set of wind-solar-storage-charging multi-energy complementary integrated energy system in the factory area is designed and implemented. The AC-DC coupled microgrid system can effectively solve the impact on the power grid during the charging of electric vehicles and reduce the power capacity occupancy rate. This project has accumulated rich experience for enterprises in the field of integrated energy multi-energy complementary, and has positive demonstration significance for the promotion of multi-energy complementary, high-voltage DC fast charging and the development of energy storage industry.

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