An Integrated Energy Power Generation with Energy Storage System

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Abstract. How to consume new energy power generation is a very common problem, if we don't take effective measures, the situation will become more and more serious. Through the application of new energy generation and storage energy management technology, can enhance the level of intelligent low voltage distribution with effectively alleviate this problem. This paper studied the basic control theory of new energy generation and storage system energy management technology, the software support platform based on dispatching automation, to advanced applications as a means to embody the control strategy, research and development of new energy generation and storage system to the management, provide technical support and the effective guarantee for the safe and stable operation of new energy power generation.

1. Introduction

Green creates the future, low-carbon economy is not only a matter of a country or an industry, it is related to the future of mankind. It has become a global consensus to vigorously develop the new energy industry and achieve the goal of low-carbon living. Since China began to pay attention to the development of new energy sources, policies to promote photovoltaic, wind and other emerging industries have been issued continuously, and various plans such as "bright plan" and "golden sun plan" have been implemented one after another, which has injected "stimulants" into enterprises. Whether in the construction of new countryside or in urban power supply network, new energy power generation is playing an increasingly important role and becoming the development direction of power grid in China's sustainable development.

At the end of 2015, Zhangjiakou's wind and photovoltaic power generation capacity reached 8 gigawatts, and plans to increase to 50 gigawatts by 2030. This figure is higher than the current total installed capacity of all countries except China, Germany and the United States. However, Zhangjiakou's local electricity demand is only 1.85 gigawatt and its outgoing capacity is only 5.5 gigawatt, not to mention how new energy generation will be absorbed in the next five years. According to reports, the rate of wind abandonment in Zhangjiakou reached 30% in 2014. If no measures are taken to improve the absorption capacity of renewable energy, the situation of wind abandonment in Zhangjiakou will be more serious. "New Energy Generation+Energy Storage" system is a small power generation and distribution system composed of new energy generation, energy storage devices, energy conversion devices, related loads, monitoring and protection devices, which can be realized.

This paper studies the energy management technology of "new energy generation + energy storage" to solve the key problems affecting the development of new energy industry, which can promote the future development of new energy industry.
Self-control, protection and management of the autonomous system, with small power capacity, can also solve the problem of power supply in remote areas, is the best way to reflect the advantages of energy conservation, emission reduction, safety, flexibility and other energy development. Small, low voltage level, close to the load center, flexible operation mode, networking and island operation characteristics, high reliability, blackout probability.

2. System architecture

The energy management system of "New Energy Generation + Energy Storage System" includes intelligent terminal, system controller and SCADA subsystem. Photovoltaic inverters, energy storage inverters and other devices have corresponding mode controllers to achieve local control. The configured smart meter collects electricity information and uploads real-time data to the smart terminal using RS485 bus Modbus RTU protocol. On the one hand, the intelligent terminal collects the real-time data of smart meter data, inverter data, bus operation, secondary equipment protection information and so on, and uploads the collected data to the system controller in real time using ethernet. On the other hand, it receives the control strategy instruction information issued by the system controller through the Ethernet TCP/IP protocol, and parses the instruction information to obtain the control instruction and control the connection. The contactor, circuit breaker, secondary equipment protection device and other executing units respond to the action.

On the one hand, the system controller receives the data uploaded by the connected intelligent terminals, collates the data, and makes logical judgement according to the pre-set control strategy of the microgrid, gets the microgrid control criteria to execute the instructions, and returns the control instructions to the corresponding intelligent terminals; on the other hand, it uses Ethernet to access the main station server of the microgrid energy management system, and uploads the microgrid real-time data to the backstage microgrid energy management system. SCADA subsystem is the main man-machine interface. It can monitor the operation of the whole system and meet the needs of intuitive, convenient, safe and reliable operation of operators.

The energy management system architecture is shown in Figure 1.

2.1. Intelligent terminal

Intelligent terminal is mainly composed of software platform, acquisition and control module, main control module and communication module. It can meet the system requirements in real-time and operational reliability. Its structure module diagram is shown in Fig. 2.
Software platform: run QNX real-time operating system and self-developed real-time database, as a control module to store data of lower equipment and execute upper control commands.

Acquisition and control module: divided into digital and protocol acquisition and control. On the one hand, the state of the circuit breaker can be collected (DI), and the action of the circuit breaker can also be controlled (DO). On the other hand, real-time data information such as smart meters, photovoltaic inverters, energy storage controllers, active filter controllers, secondary protection devices can be collected and controlled by RS485 interface (Modbus communication protocol) and Ethernet interface (standard IEC60870-5-103 communication protocol). The parameter setting, start-stop and other actions of these devices.

Main control module: uses an AMD processor clocked at 500 MHz, in conjunction with onboard DDR333 system memory, single 10/100Mbps Ethernet, four USB (Universal Serial Bus) 2.0 for easy system expansibility, VGA (Video Graphics Array) interface is used to output display signal. QNX Operating System Runs on the CF Card.

Communication module: On the one hand, the data information stored in the main control module is uploaded from the Ethernet interface to the database of the micro-network system controller by using the self-defined communication protocol, on the other hand, the micro-network control strategy command information issued by the micro-network system controller is received, and then the command information is parsed to obtain the control instructions and transmit them to the main control module.
2.2. system controller
The hardware platform of the system controller takes multi-core Core Processor as its core, and has powerful shaping and floating-point computing capabilities. The software platform uses QNX real-time operating system, self-developed real-time database management system and process control language, which has high real-time performance, operational reliability and flexibility. In this paper, the process control language is used to realize the energy joint dispatching algorithm of "new energy generation + energy storage", which can meet the complex and changeable control requirements of the system.

3. Energy Management Technology

3.1. Control method

3.1.1. Object function
Under the mode of grid-connected operation, the exchange power between the microgrid system and the power grid can be adjusted to cut the peak and fill the valley of electricity price.

\[ P_s + \sum_{i=1}^{5} P_{i}(i) + P_E + P_C = \sum_{j=0}^{n} P_{j}(j) \]

In the formula, \( P_{i}(i) \) is the generation power of the first photovoltaic module \( i \), \( P_C \) is the power of triple generation, \( P_{j}(j) \) is the power consumption of group \( J \) load, \( P_B \) is the power of energy storage system, \( P_E \) is power exchange between microgrid system and power grid.

3.1.2. Grid-connected feedback control

Grid-connected feedback control is shown in Fig. 2. Under grid-connected mode, the target value of \( P_E \) is determined by the range of switching power between the microgrid and the municipal power that needs to be controlled. From the economic point of view, the micro-grid system should consume as little electricity as possible. The difference between the target value and the current sampling value of \( P_E \) is obtained. After PI adjustment, the target value of \( P_G, P_S \) and \( P_B \) are obtained. After a delay of \( \Delta T \), the output value of \( P_E \) is sampled again for the next round of adjustment.

3.2. Independent Control Strategy of Photovoltaic System
Under the independent control mode of photovoltaic power generation, the output of photovoltaic inverters is usually controlled by maximum power tracking. Choose grid-connected inverters that can adjust output as far as possible, so as to switch to micro-grid control mode when necessary, and achieve the purpose of system control by adjusting output. If the output power can not be controlled, the regulation of photovoltaic power generation can only be realized by controlling the input or removal of photovoltaic inverters.

3.3. Charge and Discharge Control Strategy of Energy Storage System

3.3.1. Charging Control of Grid Connection
In the grid-connected charging state, the energy storage battery is charged by absorbing electric energy through the AC bus. When the battery voltage is lower than the set voltage, the conditions of grid-
connected energy storage system, normal communication of energy storage system and normal operation of energy storage system are determined in turn, and the charging mode is adjusted remotely after meeting the conditions. Energy storage inverters automatically select charging stages according to the current charging status of batteries, which can ensure the charging quality of batteries and prolong the service life of batteries.

3.3.2. Grid-connected discharge control
In the grid-connected discharge state, constant power control is adopted to determine the discharge control strategy of the energy storage system according to the current "new energy generation + energy storage system" and power exchange of the grid.

3.4. Energy Efficiency Optimized Control Strategy
The demand side response is studied on the basis of real-time electricity price. Through peak-valley price regulation, the demand-side response load regulation and distributed power supply can be achieved to cut peak and fill valley. Distributed generation has positive peak regulation characteristics for power grid itself. For energy storage systems, the peak and valley areas of load are usually used as the boundary points for battery mode switching when participating in peak and valley filling. When the electricity price is low, the output of each distributed generation is regulated with the goal of full energy storage system. When the photovoltaic power is greater than the load consumption power, the storage battery is charged, while the triple supply system is in standby state without the need of hot and cold water, and the surplus energy is sent back to the city grid; when the photovoltaic power is less than the load consumption power, the storage system is charged, and the triple supply system is in standby state without the need of hot and cold water. Consumption of electricity to meet the power balance.

4. System function

4.1. Information Acquisition and Communication Function
Information data acquisition is mainly realized by intelligent terminal, which is an important data acquisition and instruction execution device. On the one hand, intelligent meter data, inverter data, bus operation data, secondary equipment protection device data are collected circularly, and the collected data are uploaded to the system controller in real time using ethernet, on the other hand, the system controller is received through Ethernet TCP/IP protocol sends control strategy instruction information, parses instruction information to obtain control instruction, and commands the contactor, circuit breaker, secondary equipment protection device connected to the executive unit to respond to action; data acquisition part is an important part of the intelligent terminal. Communication function is the communication function in the "new energy generation + energy storage" system. It mainly uses SCADA and system controller based on Ethernet mode, communication between intelligent terminals, and communication between intelligent terminals based on RS485 serial bus mode and field devices to realize the function of data acquisition upload and control command download.

4.2. Real-time monitoring and operation
The system provides modeling tools and drawing tools, which can draw display interfaces and configure component data sources according to the configuration of "new energy generation + energy storage" system. The main interface is used to display the running state of the system, and to operate and configure it manually. The main interface system display includes the following five parts: photovoltaic power generation and grid-connected system, energy storage and grid-connected system, wind power generation and grid-connected system, operation status monitoring system of control system, load monitoring system, etc. The monitoring contents of the above subsystems include equipment information and corresponding branch measurement information. The main interface dynamically displays important information such as system voltage, current, power, contactor status and operation
status, and can be configured by users. Through component links, you can see the relevant details, can be modified according to the actual situation, should provide editing and modification tools.

4.3. Advanced Application Functions
The system can realize the following advanced application functions:

- Energy efficiency analysis
- Short-term/ultra-short-term forecast of solar intensity, wind speed, photovoltaic/wind power generation capacity and load, etc.
- Charge/Discharge Management of Batteries
- Power Flow Calculation with Distributed Generation
- Power quality analysis
- Automatic Generation Control with Distributed Generation
- Economic dispatch of distributed generation
- grid-connected and island mode switching
- Demand Side Response and Management Considering Distributed Power Supply
- Plug and Play for Distributed Power Supply

The analysis, prediction and calculation results of the above advanced application functions can be given and printed in the form of various graphics, curves, reports and dynamic information.

4.4. Energy management according to the set control strategy

4.4.1. Operation mode management
- Grid-connected operation mode
When the "new energy generation + energy storage" system runs in the grid-connected state, the charging and discharging modes of the bidirectional energy storage inverters are continuously controlled according to the switching power of the power side of the grid-connected switch. The output of the photovoltaic and fan power generation systems is dynamically distributed and the charging and discharging power of the bidirectional energy storage inverters is adjusted.

Real-time monitoring system of all loads, power supply, reactive power compensation devices, active filter devices and other operating conditions (voltage, voltage harmonic distortion rate THD, current, current harmonic distortion rate THD, frequency, active power, reactive power, power factor, active power, reactive power, reactive power, inverted active power, inverted reactive power, etc.).

- Grid-connected islanding mode
Automatic identification of grid-connected islanding status, automatic realization of grid-connected islanding mode conversion.

- Isolated Island Operation Mode
On the basis of guaranteeing the stable operation of the system and aiming at minimizing the consumption of energy storage battery, the intelligent grouping switching of photovoltaic power generation system is carried out to maximize the operation time of bidirectional energy storage inverters, and then to maximize the island operation time of the system under the failure state of the municipal power grid.

- Island-to-grid mode
Automatically identify the islands to be connected to the grid, and automatically restore the power supply after the city power returns to normal.

4.4.2. Energy management
- Automatic realization of remote start-up, shutdown and automatic regulation of the output active power of the triple supply system;
- Automatic recognition and switching of operation mode, setting of charging and discharging mode and regulating of charging and discharging power of bidirectional energy storage inverters are realized.
• Control or regulate flue gas three-way valve, hot water three-way valve and heat source water valve according to the control logic of the three-way supply system.
• Shunting input and exit of secondary and tertiary loads.
• Input and exit of active filter and reactive power compensation equipment.
• Automatic recognition and processing of four operation modes.

5. Conclusion

With the implementation of smart grid development strategy, "new energy generation + energy storage" system will get great development opportunities. Moreover, it has great potential in social and economic benefits. The application of energy management technology of "new energy generation + energy storage" will help to comprehensively improve the intelligent level of low-voltage distribution and distribution; help to save energy and reduce emissions; help to improve the level of enterprise management, reduce operating costs; and improve the reliability and safety of power grids and users.

This paper studies the basic control theory of energy management technology of "new energy generation + energy storage" system. Based on the software support platform based on dispatching automation, advanced application and control strategy, energy management of "new energy generation + energy storage" system is developed, which provides effective technical support and guarantee for the safe and stable operation of new energy generation.

Compared with other methods, the method described in this paper can achieve energy efficient utilization and improve power supply reliability through scientific dispatch of different forms of energy within the microgrid.

6. References

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