Development of Intelligent Distribution Network Simulation System Based on Distributed Generation

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ABSTRACT

With the rapid development of distribution network and distributed power generation, and the improvement of network intelligence and digitization, intelligent power consumption and the access of distributed power generation access, as the main function of intelligent distribution network, has impact on the operation of intelligent distribution network. A simulation system based on the intelligent power consumption system, photovoltaic generation, wind power generation and other distributed generations is researched and developed. By researching the operating characteristics of each subsystem, the protection and control strategy of intelligent distribution network, it can be used to research the influence of distributed power generation and intelligent power consumption on the operation of intelligent distribution network. At the same time, it can also be used as a training system.

Keywords: Distributed generation; intelligent power consumption; intelligent distribution network; simulation system.

INTRODUCTION

In recent years, the development of new energy and renewable energy power generation system is supported in the world, which have made a breakthrough both in the technical field and scale. At the same time, the distribution network is developing with intelligence. Distributed generations combining with power grid have the possibility of stable operation because of less investment, flexible power generation, and good environmental compatibility and so on. Therefore, the distributed new energy power generation system, as a new industry, is currently added to the intelligent distribution network. But numerous small capacity power are embedded in the power grid originally designed for large-scale centralized power plant, which will bring great changes to the run and control of modern power system. This trend for the traditional distribution network model is very challenging.

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A simulation system based on the intelligent power consumption system, photovoltaic generation, wind power generation and other distributed generations[1], can adjust the operating modes of distributed powers and storage system according to dispatch order and the condition of intelligent power usage, which can be used to research the control strategy of intelligent distribution network including various distributed powers and study micro-grid[2-3].

THE PHYSICAL SIMULATION and AUTOMATIC MONITORING SYSTEM of INTELLIGENT DISTRIBUTION NETWORK

Overview of the System

The physical simulation and automatic monitoring system of the intelligent distribution network is independent planed and designed, based on the rapid development and application of the new energy power generation and grid-connected, intelligent distribution network and other new technologies. It was researched and developed by many domestic universities, research institutions and equipment manufacturers, used the physical simulation, optical fiber communication, Ethernet networking, wide area protection and measurement, configuration software development, large-scale database, automatic monitoring, advanced power distribution automation and other core technical means.

This system takes the intelligent distribution network as the simulation object, and considers many factors, such as the integration of the new energy, the change of network topology and operation mode, which has strong forward-looking, theoretical significance and application value. The primary simulation system using the grid and modular design, with high flexibility and versatility, can easily simulate the different sizes, different structures and operating modes of the power grid; It can be compatible with the integration of the new energy power generation, preset multiple points of failure, to fully simulate the power grid of various failures.

Structure of the System

As shown in Figure 1, the system consists of three parts: the primary physical simulation system, the wide area protection and measurement system, the monitoring and advanced application system.

![Figure 1. Structure of the System.](image)

Four units make up the primary physical simulation system and each unit has the similar structure. They can run independently and also can run as a system at the same time. So a variety of sizes, different structures and characteristics of the grid can be simulated. Each unit uses a π type of equivalent circuit, with a variety of wiring, and is equipped with remote
control operation of the switch. The fault points are preset at different locations in each unit to simulate various types of short-circuit faults. The structure of the π type equivalent circuit is shown in Figure 2:

![Figure 2. Equivalent Circuit of the System.](image)

**Design Ideas and Functions of the System**

a. The system simulates an intelligent distribution network system. The main power supply is the actual power grid and multi-channel power supplies are designed in order to ensure the reliability of power supply.

b. With the modular design ideas, the system has a total of four operating units. Each unit can run independently and run simultaneously, and support to modify the network structure and change the mode of operation, which is greatly flexible.

c. The system can be compatible with multiple types of new energy grid-connected. A variety of new energy compose micro-grid[4] and are access to the system, accepting dispatch and control.

d. The analog load and the actual load are included in the system. The analog load combined with R and L, and can simulate different types of load; the actual load is a part of the equipment in the building, such as computers, air-conditioning and so on.

e. There are a variety of wiring methods in the system, such as single bus, single bus-bar section, double bus, double bus with bypass and so on, which can simulate various operating methods.

f. The line cascade of multi-level π-type is used to simulate the system line and by changing the π-type circuit parameters can change the length of the analog line. Multiple fault points are preset to simulate a variety of types of short-circuit fault at different locations.

g. The automatic monitoring function of the system can be realized. At the same time, the remote sensing, remote control, remote of the whole network are realized based on the communication technology of Ethernet passive optical network (EPON).

h. The relay protection of the analog grid can be realized with the principle of wide area protection.
i. It has the function of the fault recorder. The data master station of the fault recorder is developed, and the fault recorder data can be analyzed and calculated.

j. The protection settings can be set remotely. The check and modify online of all protection settings can be carried out from the monitoring side of the host.

k. Distributed new energy power generation can be dispatched and controlled.

PHOTOVOLTAIC POWER GENERATION SYSTEM

Overview of the System

The system consists of the photovoltaic (PV) integration system and energy storage system. Among them, the photovoltaic integration system is mainly composed of PV array, lightning protection box, inverter, solar power generation monitoring system and other components; The energy storage system is made up of the battery pack, bi-directional converter, battery monitoring system and so on.

The battery can be charged by power grid, and the power stored in the battery can be inverted into the standard three-phase power for the loads of micro-grid system. The current, voltage and internal resistance of each single battery in all battery packs can be monitored by battery on-line monitoring system. The entire battery energy storage system can be controlled by the energy storage monitoring system, including charging, discharging, power output, battery monitoring and so on.

The PV photovoltaic integration generation system includes 10kw monocrystal silicon PV module and 10kw polycrystal silicon PV module. It's convenient to compare their power generation situation so that the students can more clearly grasp the characteristics of different materials.

This PV generation system can be integrated to the intelligent distribution network and it can be dispatched when the distribution network fails.

Structure of the System

The structure is shown in Figure 4 and the picture is shown in Figure 5.

Figure 4. Structure of the PV Generation System.
Design Ideas and Functions of the System

a. The micro-grid composed of PV generation system and the other new energy, can be integrated in the intelligent distribution network to operate, which can be used as power or load in operation and receive distribution network scheduling.

b. The system is equipped with experimental devices, so the characteristics and factors of PV cells can be researched and studied.

c. Though the comparison of monocrystal silicon PV module and polycrystal silicon PV module, the characteristics of PV array and the difference between different materials can be understand in depth.

d. Through the battery monitoring system, it is fully understand that energy storage system plays an important role in PV generation system.

WIND POWER GENERATION SYSTEM

Overview of the System

The motors are used to simulate the wind rotors, dragging the generators to simulate wind turbines. The wind power generation simulation system includes two sets of permanent magnet direct-drive wind turbine platforms (5kw each) and two sets of DFIG wind turbine platforms (5kw each).

The small-scale DFIG simulation system is constructed to simulate the static and transient operation characteristics of DFIG and simulate the evolution from the sub-synchronous operation to the ultra-synchronous operation of DFIG with the wind speed changes.

The low voltage drop test can be carried on to test the ability of the low voltage ride through (LVRT). The depth and recovery time of the voltage drop can be set by the system.

Structure of the System

The structure of permanent magnet direct-drive wind turbine is shown in Figure 6 and the structure of double-fed induction generator (DFIG) wind turbine is shown in Figure 7. Their pictures are shown in Figure 8.
Figure 6. Structure of Permanent Magnet Direct-drive Wind Turbine.

Figure 7. Structure of Double-fed Induction Generator (DFIG) Wind Turbine.

Figure 8. Picture of the System.

a. Picture of Permanent Magnet Direct-drive Wind Turbine

b. Picture of Double-fed Induction Generator (DFIG) Wind Turbine
Design Ideas and Functions of the System

a. The micro-grid composed of wind power generation system and the other new energy, can be integrated to the intelligent distribution network to operate, which can be used as power or load in operation and receive distribution network scheduling.

b. Through the simulation of the static and transient operation characteristics of the wind turbine and the operation of the intelligent distribution network, it fully reflects the advantages and disadvantages of the two wind turbines, and its impact on the grid.

c. The low voltage drop test can be carried on to test the ability of the low voltage ride through (LVRT). The depth and recovery time of the voltage drop can be set by the system.

d. Through the battery monitoring system, it is fully understand that energy energy storage system plays an important role in wind power generation system.

BATTERY ENERGY STORAGE SYSTEM

Overview of the System

The battery energy storage system includes battery pack, bi-directional storage converter, battery online monitoring system and management system four parts.

The battery pack consists of two groups lead-acid battery with 300Ah / 2V and two groups colloidal battery with 300Ah / 2V. There are 24 batteries in series in each group, composing 48V / 300Ah system and 96 batteries are totally included in four groups, which are as the system’s main energy storage components.

This battery energy storage system can be integrated to the intelligent distribution network and it can be dispatched when the distribution network fails.

Structure of the System

The structure is shown in Figure 9 and the picture is shown in Figure 10.

Figure 9. Structure of the Battery Energy Storage System.

Figure 10. Picture of the System.
Design Ideas and Functions of the System

The battery energy storage system can be placed, dispatched and controlled in summary.  
a. Through the monitoring of the working conditions of the bi-directional storage converter, the system can be response to the control command of the host computer and achieve the functions, such as charging, discharging, the adjustment of the output power. 
b. The functions which the storage system has in the new energy integration system are studied through the working status of the energy storage system.  
c. The advantages and disadvantages of various battery energy storage system can be compared clearly.

INTELLIGENT POWER CONSUMPTION SYSTEM

Overview of the System

The intelligent power consumption system is composed of the intelligent electricity monitoring and control system, power consumption simulation sand table, power consumption equipment. The various loads in the power consumption simulation sand table with different load conditions, and the electricity status of intelligent power consumption equipment are real-time monitored and analyzed. The intelligent power consumption control strategy can be optimized through the interaction with the grid information. 

Intelligent power consumption strategy demonstration system relies on the strong power grid and modern management concept, using advanced measurement, efficient control, high-speed communications, intelligent simulation technology. The city electricity load forecasting, time scheduling, load priority, peak load shifting and other control strategies are shown through intelligent sand table demonstration, which could meet the research needs and reflect interactive, intelligent and scientific of the system. The picture of the system is presented in Figure 11.

Intelligent home system is to make full use of advanced computer, network communications, integrated wiring and other technical means. It could carry on the communication and data exchange with the household appliances through different interconnection means and display the network integrated intelligent control, management, energy consumption analysis of the household appliances through Intelligent home system, which can meet the teaching and research needs.
CONCLUSION

With the rapid development of new energy power generation and intelligent distribution network, intelligent distribution network with distributed new energy power generation and intelligent power consumption will become the common operation mode in the future. The five systems constitute an intelligent distribution network, and it can be in independent and grid-connected operation. All kinds of new energy power can accept the dispatch of intelligent distribution network. It is very important to research the operation mode of intelligent distribution network and the safe operation of power grid.

REFERENCES