Distributed New Energy Micro-grid Absorption Pilot Project in Northeast China Power Grid

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Abstract—**SIE micro-grid is a demonstration research project of microgrid in Liaoning Province of China, this paper introduces the construction scheme, equipment and its functions, operation control mode, some test results and subsequent development directions of the microgrid in details and also emphasizes the coordinated control method and experimental situation of the microgrid under the isolated operation conditions, providing references for the practical engineering application of the micro-grid project and the local consumption strategy of the new energy.**

Keywords-component; micro-grid；Northeast China Power Grid；Distributed New Energy

I. Introduction

In 2018, the total installed capacity of new energy in Northeast Power Grid accounted for 26% of the total power supply capacity, and the generation of new energy accounting for 15% of the total power generation of the Northeast Power Grid. The current new energy installations of the Northeast Power Grid are mainly large wind and PV power plants with large-scale centralized development, transported over long distances. In recent years, the explosive growth of distributed new energy consumed on the spot has grown at an average annual rate of more than 100%. How to manage the explosively grown distributed new energy has become a new issue facing the Northeast Power Grid[1-3].

If all the distributed power sources are freely and randomly integrated into the large power grid without authorization, all the shortcomings of the distributed new energy sources will be borne by the large power grid, which will inevitably have an excessive impact on the safe and stable operation of the large power grid[4-6]. It is a technical route for the Northeast Power Grid to cope with the development of distributed new energy in the future by organizing and managing some distributed power sources in a certain area with microgrid and then interconnecting it with the large power grid[7,8].

The Northeast Branch of the State Grid Corporation and the Shenyang Institute of Engineering jointly conduct a pilot project study on the consumption of distributed new energy microgrid. At present, a relatively complete experimental technology innovation platform integrated with wind, PV, storage (energy), micro (multi-level micro-grid), consumption (load and charging pile) has been built. The platform integrates solar power generation, system control theory and technology, wind power generation, power conversion device and detection control technology, micro-grid control system and smart home, charging car integrated charging operation and other technologies, etc.

II. SIE microgrid configuration

2.1 Main equipment of SIE microgrid

Wind turbine FD12-30, the diameter of the wind wheel is 12m and the rated power is 30kw. The permanent magnet synchronous generator is directly driven by the wind wheel, and the auxiliary electric starting function is added. The system consists of a set of 30kw simulated wind turbine system, a set of 20kw PV power generation simulation system and a 63KVA analog electronic load.

A set of 15kw monocrystalline silicon, centralized inverter photovoltaic group, 12kw polysilicon, micro-inverter photovoltaic group, the angle of the two sets of photovoltaic groups can be adjusted.

The energy storage is composed of super capacitor, lithium iron phosphate and lead carbon battery. The capacity of super capacitor is 0.6MJ, the rated power of lithium iron phosphate battery and lead carbon battery is respectively 25kw/h and 50kw/h.

The monitoring system includes microgrid energy management system, photovoltaic power generation monitoring system, battery energy monitoring system, and wind turbine monitoring system. It can monitor the generated power and power quality, make real-time analysis of voltage, frequency and other indicators in real time; it can also monitor current battery status in real-time, emit audible and visual alarm to abnormal signal, and the CDMS online monitoring system uses sound and vibration combined monitoring. Carry out fault diagnosis on the wind turbine.

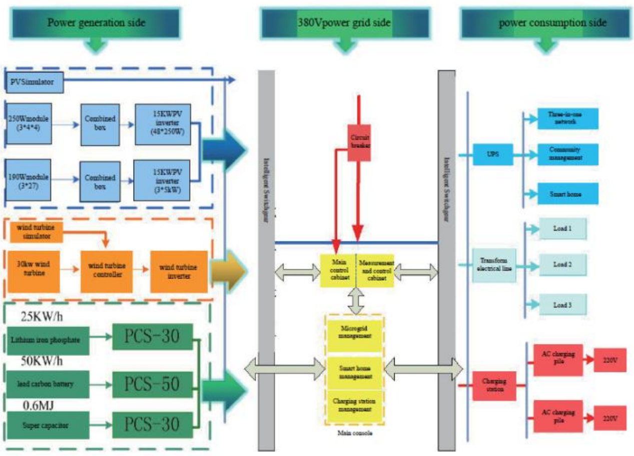


Fig.1 Overall frame structure of power grid lab

2.3 The composition of the SIE system is as follows:

1. Microgrid energy management system

(1) Application software layer: including data acquisition and monitoring; load forecasting, renewable energy power generation unit output prediction; economic optimization operation;

(2) Mathematical modeling layer: mathematical modeling of software function analysis; basic data layer: management of the basic data required for software operation.

(3) Control system: The control system consists of a protection device, a measurement and control device, and grid-connection and grid-off controller.

2. Smart home system

The smart home system consists of smart terminals, smart switches, smart sockets, smart meters, and wired/wireless IoT networks. The smart terminal device is the core of the smart home, and it runs an integrated management platform to realize intelligent management and control of the household appliances.

The project integrates multiple subsystems such as smart home appliance control system, lighting scene control system, home energy efficiency management system, new energy access system, video intercom system and intelligent security system, etc.

3.Charging system

The electric car charging system is mainly composed of an AC charging pile and a charging station monitoring system.

III. SIE MICROGRID TOPOLOGICAL STRUCTURE

A flexible multi-level network operation structure that realizes variable structure operation and control of AC/DC hybrid microgrid.

The wind power generation unit is connected to the busbar M1 via the interconnection switch F1, and the photovoltaic power generation grid connection unit is connected to the busbar M1 via the interconnection switches F2-F4, and a set of equipment in the energy storage unit is connected to the busbar M1 via the interconnection switch F5, the other set of equipment in the energy storage unitis connected to the busbar M2 via the interconnection switch F11. The analog load is connected to the busbar M2 via the interconnection switch F9, the inverter output is connected to the PVSimulator input, and the PVSimulator output is connected to the busbar M2 via the interconnection switch F10. The busbar M1 and the components connected thereto form a microgrid and the busbar M2 and the components connected thereto form another microgrid, Ml and M2 are connected through cable and is provided with a interconnection switch K2, M1 and M2 are respectively connected with busbar M3 by cables, and the two cables are respectively provided with interconnection switches K3 and K4. The busbar M3 is connected to the external power grid via the interconnection switch K1 and transformer; communication network is provided between interconnection switches, and is connected with central controller through the field bus, to achieve information collection and control of the switch state.

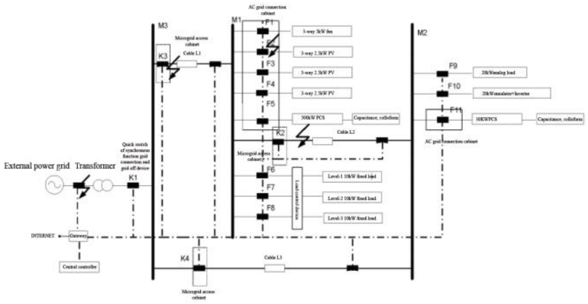


Fig. 2 Diagram for structure of microgrid experimental system

Through the state of each interconnection switch, different operation modes and configuration modes of multiple microgrids can be realized, and related networking experiments can be carried out in different operation modes. The operation modes of the multi-microgrid mainly include the following: single-microgrid interconnection mode, multi-microgrid connection mode, single-microgrid island mode, multi-microgrid island mode and transient mode, the networking mode is closely related to the state of the interconnection switch, specific as follows:

1. Single-microgrid connection mode

When the interconnection switches K1 and K3 are closed, K2 and K4 are disconnected, and the system is in the single-microgrid connection mode; the following situations may exist at this time:

①When F1 is closed,the wind turbine drives the load;

②When the F2-F4 are closed, the cell module of PV power generation connection unit drives the load;

③The load is driven by the energy storage unit only when F5 is closed.

2. Multi-microgrid connection mode

When the interconnection switches 1U-K4 are closed, the system is in the multi-microgrid connection mode.

3. Single-microgrid island mode

When the interconnection switches K1-K4 are disconnected, the system is in single microgrid island mode.

the following situations may exist at this time:

①When F1 is closed, the wind turbine drives the load;

②Only when the F2-F4 are closed, the cell module of PV power generation connection unit drives the load;

③The load is driven by the energy storage unit only when F5 is closed.

4. Multi-microgrid island mode

When the interconnection switch K2 is closed and K1, K3, and K4 are disconnected, the system is in the multi-microgrid island mode.

5. Transient mode

The fault point is preset, when a fault occurs at a preset fault point, the system is in the process of switching from the grid connection to the island. At this time, it is in the transient mode.

IV. Isolated operation control of SIE microgrid

4.1 Coordinated control of wind- storage isolated grid system with multi-agent technology

As shown in Fig. 3, the coordinated control of the wind storage isolated grid system based on multi-agent technology is realized by establishing a two-layer agent control model: the upper-layer is for central coordination of the control agent and the lower-layer is the unit decentralized control agent. The lower-layer unit agent decentralized control is realized by adding a local controller to the wind power generation system, the inverter of the energy storage unit and the load terminal. The main function of the lower-layer unit agent decentralized control is to sense the operating state of each unit such as the wind power generation unit and the energy storage unit in the system, and to control local indicators such as power and voltage, etc. and simultaneously communicate with the upper-layer central agent or the adjacent lower-layer decentralized agent, implementing coordinated control. The upper-layer coordinated control agent makes decisions and judgement as well as carries out analysis and calculation of decision strategies through historical data information, the system monitors information and the communication information with each agent, and issues the action execution command to the coordinated control command module, and sends command to the lower unit decentralized control agent through the communication channel. In the wind storage isolated grid system, there is interaction between the upper coordinated control agent and the lower unit decentralized control agent, and the interaction between the upper coordinated control agent and the lower unit decentralized control agent is realized through direct action, while the interaction between the lower unit decentralized control agent and the upper layer coordinated control agent and the lower unit is realized by indirect action. The interaction process model between upper coordinated control agent and the lower unit decentralized control agent is shown in Fig. 3.

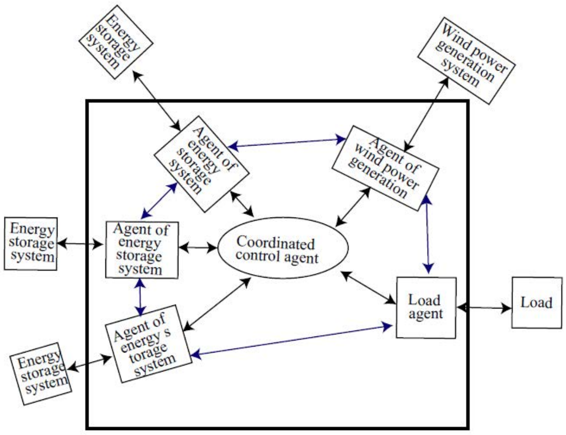


Fig. 3 The interaction process model between upper coordinated control agent and the lower unit decentralized control agent

4.2Emergency power balance control of wind storing isolated grid system can be expressed as the following optimization control problems:

$$\min F = \sum_{i=1}^{N_S} f_{Si}(\Delta P_{Si}) + \sum_{i=1}^{N_W} f_{Wi}(\Delta P_{Wi}) + \sum_{i=1}^{N_D} f_{Di}(\Delta P_{Di})$$

$$\Delta P = \sum_{i=1}^{N_W} P_{\text{wi}} + \sum_{i=1}^{N_S} P_{Si} - \sum_{i=1}^{N_D} P_{Di}$$

$$\Delta P = \sum_{i=1}^{N_S} \Delta P_{Si} + \sum_{i=1}^{N_W} \Delta P_{Wi} + \sum_{i=1}^{N_D} \Delta P_{Di}$$

$$\zeta^{\min} P_{Si}^{\min} \le P_{Si}^{0} + \Delta P_{Si} \le \zeta^{\max} P_{Si}^{\max}$$

$$\Delta P_{Di} \le P_{Di}^{0}$$

Where： ΔP indicates the difference value in active power required during the coordination of active power balance by the system, and the value is equal to the difference between all power factors, all stored energy power and all load power in the wind storage system; ΔP_{Si}, ΔP_{Wi} and ΔP_{Di} are respectively expressed as stored energy output power, generator tripping power and load shedding power that need to be adjusted to restore the power balance of the system where they are control variables; f_{Si}, f_{Wi} and f_{Di} are respectively cost functions corresponding to the above power adjustment; P_{Si}^{0} is the initial power of the i energy storage unit; P_{Di}^{0} is the initial load power of the i load; $\zeta^{\min}$ and $\zeta^{\max}$ are the margin coefficient of stored energy power, ensuring that the system still has the ability for smooth running of the microgrid after emergency power control; $P_{Si}^{\min}$ and $P_{Si}^{\max}$ are the maximum and minimum regulated power of the energy storage unit power;

The objective of the emergency power for isolated grid system is to achieve the lowest overall adjustment cost under the condition of restoring the system power balance.If the power difference exceeds a certain limit value and local control is difficult to effectively adjust, the upper coordination control is started. If ΔP is positive, the battery is discharged, and ΔP is minus, the battery is charged.

4.3 Mathematic model of periodic energy optimizationcontrol

The objective of periodic energy optimization control is to optimize the output of various operational controlled micro-sources and the total operating cost of the system under the condition of meeting the system operating constraints, which can be expressed as the following optimization problems:

$$\min F = \sum_{i=1}^{N_S} C_{Si}(P_{Si}) + \sum_{i=1}^{N_D} C_{Ti}(P_{Ti})$$

$$\sum_{i=1}^{N_S} P_{Si} + \sum_{i=1}^{N_T} P_{Ti} + \sum_{i=1}^{N_W} P_{Wi} = P_D + \Delta P_L$$

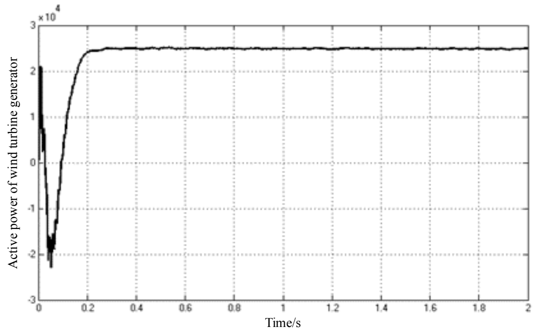
$$P_{Si}^{\min} \le P_{Si} \le P_{Si}^{\max}$$

$$P_{Ti}^{\min} \le P_{Ti} \le P_{Ti}^{\max}$$

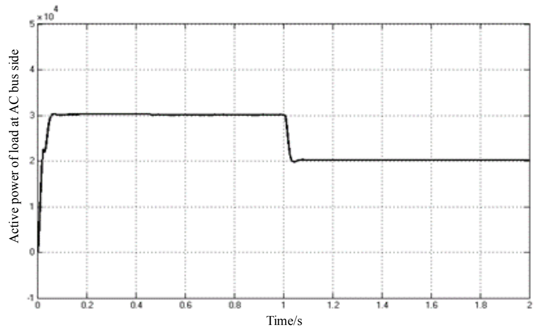
Where: P_D is the load value of system during the optimization period; ΔP_L is the network loss of system; P_{Si}, P_{Wi} and P_{Ti} are respectively the output powers of stored energy, wind power generation and other output powers for power sources (such as photovoltaic power generation) in the system; C_{Si} and C_{Ti} are respectively the cost functions corresponding to the above output powers.

V. Isolated operation experiment of microgrid

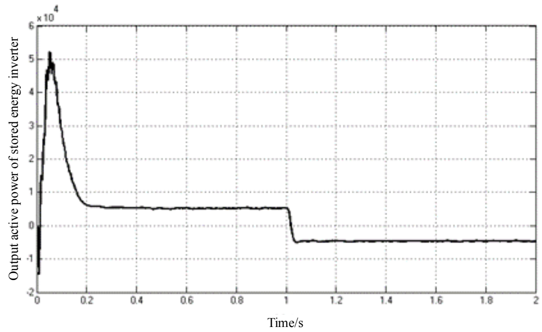
The wind-storage isolated grid system is operated at the rated wind speed under the condition of stable operation. At 1.0s, the wind-storage isolated grid system loses a load of 10kw. Under the disturbance, the simulation curve results under this fault are shown in Fig. 5.



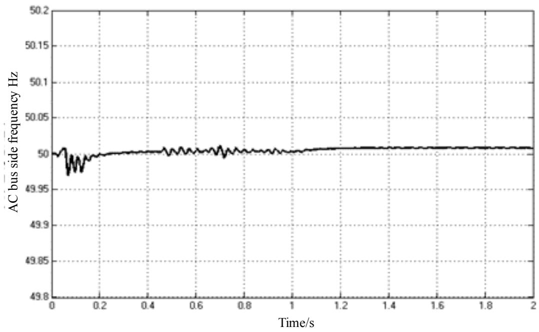
(a) Active power of wind turbine generator



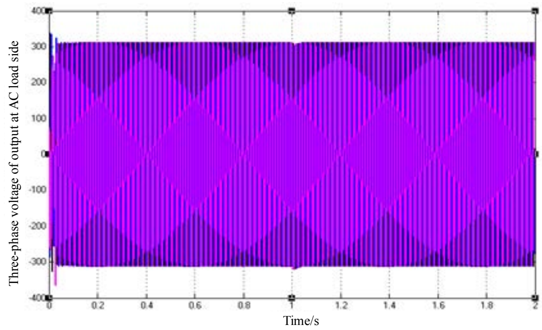
(b) Active power of load at AC bus side



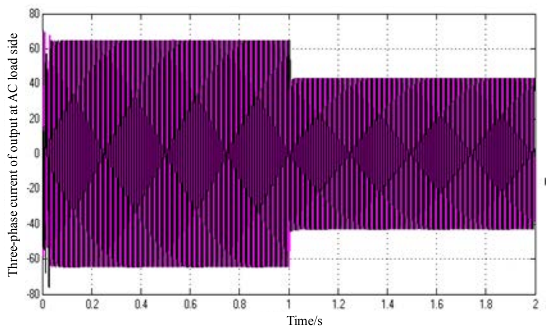
(c) Output active power of stored energy inverter



(d) Frequency at AC side of the system



(e) Three-phase voltage of output at AC load side



(f) Three-phase current of output at AC load side

Fig.5 Simulation diagram of wind-storing isolated grid system in load-shedding running status

From the results of the dynamic simulation experiment, the active power output of wind turbine generator is 25kW (Fig. a) and the load active power is 30kW (Fig. b)before 1.0s, and the battery is in a discharging state, which is used to maintain the active power balance of the wind-storing isolated grid system (Fig. c). At 1.0s, the wind-storing isolated grid system is running with loss of load, the load active power suddenly changes to 20kW, the output active power of wind turbine generator is still 25kW, the upper intelligent coordination controller acts quickly, the active power load of extra 5kW output by wind turbine generator is absorbed by storage battery, and the storage battery is in a charging state. Before and after running with load removed, the frequency and voltage output from the AC side of wind-storing isolated grid system can meet the load requirements. The wind-storing isolated grid system based on multi-agent technology of Shenyang Institute of Engineering can realize coordination and stable operation when the system runs under sudden loss of a large amount of load.

VI. Conclusion

SIE microgrid is a demonstration research project of Liaoning microgrid. This paper introduces in detail the construction plan, equipment and its functions, operation control mode, some test results and subsequent research directions for the microgrid.With the continuous expansion of grid construction and previous large-scale power outages in the world, the defects of this ultra-large-scale power system have gradually appeared, such as high construction cost, large transmission loss, difficult operation and maintenance, and unstable power consumption in remote areas. Users' requirements for diversified safety and reliability of power are difficult to be met at present. However, microgrid can be flexibly switched between grid-connected operation and isolated operation, with great development potential, but it will also encounter many technical problems. As a demonstration research project of Liaoning microgrid, Microgrid Laboratory of Shenyang Institute of Engineering has important reference significance for studying how urban communities in northeast China can promote the absorption of distributed new energy by microgrid in the future.

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