Intelligent Control Method for Load of Multi-energy Complementary Power Generation System

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Abstract. In order to reduce environmental pollution, the load of power generation system has become an important basis for the balance of power supply and demand. Therefore, an intelligent load control method for multi energy complementary power generation system is proposed. Firstly, the intelligent control scheme of multi energy complementary power generation system is formulated, the circuit principle of the control method is determined, and the frequency control parameters of power grid, frequency regulation of generator set and control mode of generator set are controlled. The experimental results show that the load intelligent control method of the multi energy complementary generation system can effectively control the load of the power generation system, and the multi energy complementary generation can smooth the randomness of single energy, the intermittent fluctuation of energy and the control effect of energy storage, and reduce the impact on the power grid, which is very suitable for distributed grid connected operation.

Keywords: Multi-energy · Complementarity · Power generation · Control

1 Introduction

Wind energy, solar energy, marine energy and other renewable energy have huge reserves, wide distribution, and no pollution in development and utilization. How to make use of these resources to transform the electric energy which is needed by the modern information society has been paid more and more attention by all countries [1]. Some islands and remote areas are far from the main power grid due to their geographical characteristics, or the power grid is difficult to set up, coupled with the lack of energy conversion technology, the living standards of residents are backward, and it is difficult to carry out industrial production, while the natural resources of the islands are often rich, so the development and utilization of renewable resources of the islands are many at one stroke. However, these natural resources are very sensitive to the climate, with small energy density and strong randomness, which can not be realized as a stable energy output or at a considerable cost [2]. Renewable natural resources have the characteristics of small energy density, wide distribution and strong randomness. According to the research of hydrodynamics, the randomness and uncertainty of wind

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energy and water energy will lead to the following changes of the frequency and voltage of the output power of wind turbine, so it is necessary to control and adjust the power in the actual operation [3]. At the same time, because of the complexity of generators and some power electronic devices, and the control technology of some system models is only suitable for some specific power systems. In addition, the wind turbine generator units are usually in remote areas, offshore or island, generally unattended, and can only be monitored remotely, which puts forward higher requirements for the matching and reliability of the control system of the generator units.

According to the current situation and development trend of wind power generation, according to the planning of the national energy administration, large-scale wind power bases are planned to be built in areas rich in resources, so as to accelerate the decentralized development of wind energy in other regions. By 2020, wind turbines will reach 200 GW. China's wind energy is distributed in the northeast, Xinjiang, Inner Mongolia and other remote areas. In this process, the stability of power grid frequency becomes the key to affect the quality of power supply [4]. Active power is closely related to frequency. The balance between supply and demand of active power under rated frequency is the basic premise of ensuring frequency quality and one of the basic methods of frequency control. However, this is a constrained nonlinear multi extremum optimization problem, which is difficult to deal with by traditional methods. Therefore, an intelligent load control method for multi energy complementary power generation system is proposed. The optimal control of generator active power output can not only realize the balance of supply and demand of active power, but also ensure the frequency stability of power generation system. It can also make the power generation system run economically. Frequency regulation is divided into one, two and three regulation. Primary regulation is the inherent characteristic of generator, and differential regulation is usually used. In order to ensure the frequency safety of the system, it is necessary to adjust the frequency twice by using the power frequency static characteristics of the generator synchronizer. In order to improve the economy of power generation system, the generator is usually optimized and adjusted, which can not only ensure the safety of system frequency, but also reduce the generation cost of power generation system.

2 Intelligent Control Method for Load of Multi-energy Complementary Power Generation System

2.1 Design the Structure of Intelligent Load Control Method for Multi-energy Complementary Power Generation System

The multi-energy storage joint generation system shares a single inverter topology as shown in Fig. 1:

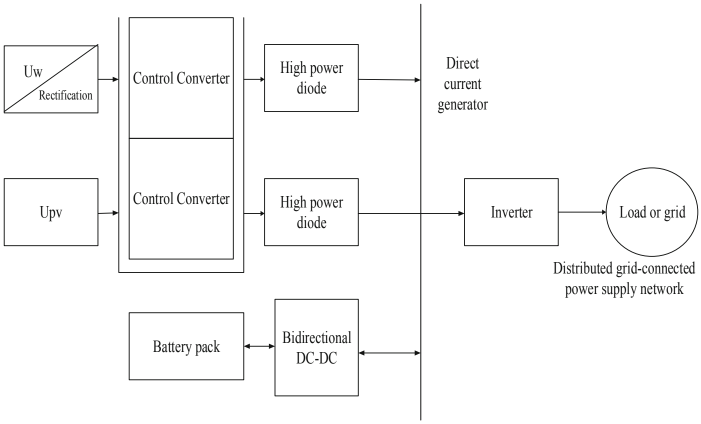

Fig. 1. Intelligent load control for multi-energy complementary power generation system

Two V2-controlled Boost-Buck converters (DC-DC) are designed on the DC side of grid-connected or inverters. The output of wind power generation converted by AC-DC rectifier and photovoltaic power generation are controlled respectively by parallel connection of high power diodes and DC bus [5]. By using common inverters, the switching between distributed grid-connected power supply and isolated off-grid power supply is realized. The multi-energy storage combined power generation system based on this topology has the advantages of low cost, suitable for edge area, good stability of fluctuation, suitable for grid-connected operation, stable DC bus voltage and simple control strategy [3].

The model is composed of three parts: strong power flow loop, weak current sampling display control loop and control program module. The discharge circuit designed in the high power flow circuit is used to adjust the multi-energy output deviation not to be too large [6].

2.2 Introduction Control Circuit Principle

When the Boost and Buck circuits are used separately, they have only a single step-up or step-down function. A Kv and A1 module are added to the Boost-Buck circuit, and A3 module is used to achieve both the effect of voltage rise and fall and the constant voltage control of the output double loop feedback (Kv-A1, outer loop Kv-A3-A2-A1) of the Boost-Buck circuit. The inner loop control can improve the transient response speed of the Boost-Buck circuit, while the outer loop control can improve the control accuracy of the Boost-Buck circuit and keep the output voltage basically constant. In practical application, the input is added and the output filter reduces the pulsation of the current [7]. The V2 control method uses the voltage of the output filter capacitor C of the Boost-Buck converter to replace the inductor current in the peak current control. As the peak voltage detection input of comparator A1 and output by single chip computer, the PWM signal compensated by skew compensation circuit is connected to JK flip-flop to modulate IGBT work. Rate tube conduction angle duty cycle signal, thus changing the inductance current and output voltage.

2.3 Calculation of Power Network Frequency Control Parameters

When the grid frequency and power change, they will have a dynamic relationship. When the power difference P, the frequency deviation f of the power grid will have the following transfer function:

$$\frac{\Delta f(s)}{\Delta P(s)} = \frac{1}{M_i s + D_i} \quad (1)$$

Formula M_i is the inertia time coefficient of the generator set, and M_i = 50–10 s is the general one. Formula D_i is the frequency regulation effect coefficient of the load (also known as the model load damping constant), then $D_i = \frac{\Delta P_{Df}}{\Delta f}(MW/Hz)$.

When D_i is replaced by a standard unitary value, it represents the percentage of load active power change caused by 1% frequency change. Take $D_i = 1$ as an example, that is, when frequency +0.01 (+0.5 Hz), the load value will be +0.01 (load 1%) and D_i = 1–3.

In primary frequency modulation of generating units, the curve of static relationship between output power and frequency of generating units becomes the static characteristics of power and frequency of generating units [8]. The slope of power-frequency static characteristic curve can be expressed as $\frac{\Delta P}{\Delta f} = K_g$.

Governor is an important part of generator set. Its main function is to maintain the load distribution and rotation speed between units. The mathematical function of steam turbine governor is $1/T_{ni}S + 1$, Of which Is the governor time factor, which is usually 0.05–0.25 s. Steam turbines convert steam stored energy into mechanical energy, which is then converted by generators into electrical energy. The transfer function of reheat steam turbine is $\frac{SCT_{Ri} + 1}{(ST_{Ri} + 1)(ST_{ti} + 1)}$. It needs to consider the time delay of steam flow in reheat system. C is the proportion of power generated before steam enters reheater, which is generally 25%–30%, TRi is the time coefficient of reheater, which is generally 5–10 s.

2.4 Regulating the Frequency of a Generator Set

Stand-alone control area: there is only one non-reheat thermal generator unit in the control area with an installed capacity of 600 MW (rotating standby capacity of 100 MW), with a load of 500 MW. at a frequency of 50 Hz We take the firepower unit's Di equal to 1Mi equal to 10. After several seconds of reduced amplitude oscillation, it finally stabilizes near the calculated value of theoretical analysis.

The wind power generation control mode and the photovoltaic power generation control mode belong to the single power supply constant voltage control mode, can be divided into two kinds of situations:

The time period of non-light radiation. The wind speed is enough to control the control mode of single Boost-Buck converter using V2 of wind power generation;

No wind speed period. Enough optical radiation to control a single Boost-Buck converter using a PV-based V2 converter;

The multi-energy complementary power generation control mode belongs to the dual power supply deviation control and constant voltage control mode, specifically: there is both light radiation and wind speed time, when wind speed, light radiation is enough, but wind, When the output voltage difference between the two photogeneration exceeds the allowable range of the Boost-Buck converter, the PWM signal is output by the bias control module of the single-chip microcomputer to make the wind power discharge circuit work, and the difference of the output voltage between the two is adjusted to the allowable value. The V2 control dual-Boost-Buck converter which starts the wind-light combined power generation works simultaneously [9, 10].

2.5 Control Generation Control Mode

The multi-energy storage combined generation control mode includes multi-energy storage and distributed grid-connected fluctuation and fuzzy control, multi-energy storage island off-grid load control and fuzzy control. The multi-energy storage and distributed grid-connected control mode is to control the switch-on direction of the bidirectional DC-DC converter under the distributed grid-connected power supply mode, according to whether the output power fluctuation of the multi-energy power exceeds the national standard [11, 12]. By controlling the start-up and stop time of energy storage or discharge, the energy storage can reduce the power wave momentum of multi-energy and reduce the impact of the power network.

The active power of multi-energy complementary generation is sampled according to a certain sampling period, and the on-off direction of switch is controlled in the circuit of bi-directional DC-DC converter. When the sampling difference between two adjacent points is positive and the absolute value is greater than the national standard, Starting energy storage to store remaining energy; When the sampling difference between the two points is negative and the absolute value is greater than the national standard, the starting energy storage releases the storage energy.

2.6 Control Load Network Load

The strategy multi-energy storage island type off-grid control mode is that the multi-energy storage combined power generation under the isolated off-grid direct load operation mode, according to the multi-energy generation power and the load demand power match or not. The on-off direction of switch is controlled in the circuit of bi-directional DC-DC converter, and the start-up and stop time of energy storage or discharge is controlled. The purpose of energy storage is to increase the follow-up of multi-energy and load and to reduce the abandoned multi-energy quantity.

For the off-grid operation model of multi-energy storage island, the multi-energy storage power in the model should be matched with the load demand power at every moment. Therefore, the multi-energy combined output is divided into three regions according to the installed capacity: peak, middle waist and low valley. The load is also divided into three regions according to the maximum load, namely, high load, medium load and low load. According to the following principles, a multi-energy storage and nine-house district control strategy based on tracking load fluctuation is formulated.

(1) When the multi-energy output and load level are in the low-valley and low-load region, the middle-waist load region and the peak-high load region, respectively, it is considered that the multi-energy combined output is in the state of natural tracking load fluctuation (positive peak-shaving), and the output of the energy storage model is set to 0 at this time.
(2) When the multi-energy output level is in the low valley region and the load level is in the high load region, or when the multi-energy output level is in the high peak region and the load level is in the low load region, it is considered that the multi-energy power output is in the state of unable to track the load fluctuation (inverse peak-shaving). Set the energy storage model to:

When $P_{ES(\mathrm{i})} \leq \left|P_{\mathrm{wg(i)}} - P_{L(\mathrm{i})}\right| - P_F$, $P_{\mathrm{wg(i)}} - P_{L(\mathrm{i})} < 0$, low valley and high charge energy storage discharge; When $P_{ES(\mathrm{i})} \leq \left|P_{\mathrm{wg(i)}} - P_{L(\mathrm{i})}\right| - P_F$, $P_{\mathrm{wg(i)}} - P_{L(\mathrm{i})} > 0$, peak low charge energy storage charge. Among them, $P_{L(i)}$ is the total load of the model at I time, PF is the setting threshold, and its setting amount is determined by 10% of the storage capacity, considering that the storage should not be filled frequently.

3 Results

According to the above-mentioned principle and conception, Xinjiang University has developed the hardware module of V2 control double Boost-Buck transform controller and the software modules of constant voltage control, fluctuation control, load control, fuzzy control and deviation control for multi-energy storage combined power generation. Physical hardware and multi-energy storage networking test platform.

3.1 Experimental Preparation

(1) In the 0:00–7:00, 20:00–24:00 non-light radiation period and multi-energy generation differential voltage greater than the allowed range of 7:00–8:00, 19:00–20:00 wind-generated V2 control of a single Boost-Buck converter control mode. The test results are qualified and meet the requirements.
(2) When the differential voltage of multi-energy generation is less than the allowable range of 7:00–19:00 time, the wind-light combined power generation V2 control dual-Boosck converter control mode, the test results are qualified voltage and meet the requirements.

Based on the control strategy of reducing multi-energy fluctuation and tracking load, positive peak shaving, flat peak shaving and reverse peak shaving frequency are used to calculate the effect of energy storage after energy storage. Table 1 gives the variation and effect of multi-energy electric power fluctuation, following load and economic index before and after adding energy storage.

It can be seen that the effect is better in stabilizing the fluctuation of multi-energy electricity, improving the characteristic of following load, reducing the amount of multi-energy electricity abandonment, increasing the utilization of resources and improving the economic benefit of multi-energy electricity.

Table 1. Economic indicators of multi energy electric energy storage

Economic indicators	Time	Fan power/kW	Photovoltaic power/kW	Photoelectric complementary power/kW
Multi energy power fluctuations	0	386.55	0	387
Subsequent load	5	290.89	0	291
Before increasing energy storage	10	398.54	703.20	1102
After increasing energy storage	15	298.10	742.40	1041

3.2 Load Comparison of Power Generation Control Mode

The multi-energy complementary charging mode and the traditional charging mode are used to charge the battery pack composed of 12 V/9 A·h battery series and parallel respectively. The dynamic curve of charging current in the two modes is shown in Fig. 2.

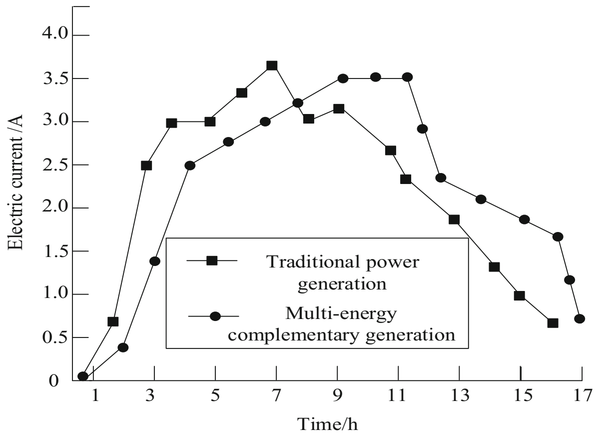

Fig. 2. Two charging current variation curves

(1) The charging time of traditional charging mode is nearly 17 h, the charging time of multi-energy complementary generation is nearly 15.5 h, and the charging time is shortened.
(2) Considering the safety problem, the maximum charging current of the battery is 4 A, the maximum current is 3 A in the traditional charging mode, and the maximum charging current is close to 3.5 A in the multi-energy complementary charging mode, indicating the fuzzy control mode. Ability to automatically identify maximum charge current.

3.3 Test of Inverter Output

In the simulation test of multi-energy storage test platform, the output voltage waveform of the inverter is compared with that of the actual field multi-energy grid-connected bus voltage recording, as shown in Fig. 3.

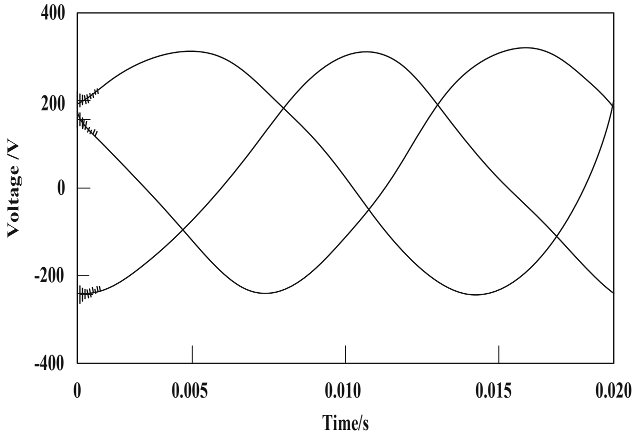

Fig. 3. Inverter output voltage ripple

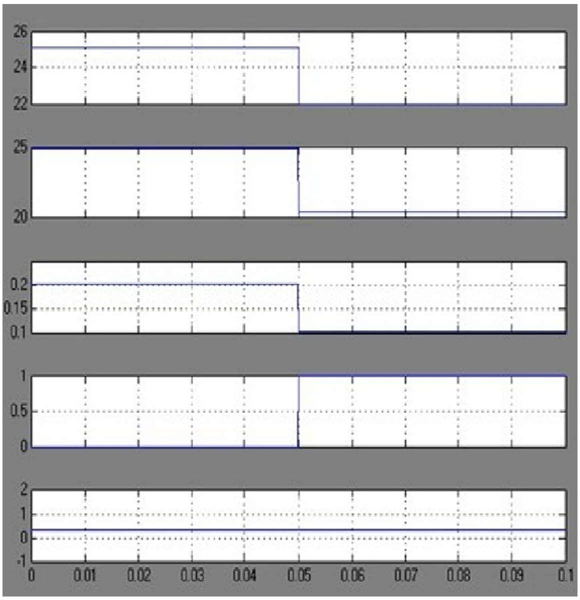

Fig. 4. Power balance results of multi energy complementary generation system when the battery is not saturated

When the battery of multi energy complementary power generation system is not full, the regulation method of load tracking will consider the state of the battery. Assuming that the current power is reduced from 25 kW to 22 kW, the SOC of the battery is 0.6. The simulation curve is shown in Fig. 4. The load tracking decision changes in 0.05 s as shown in Fig. 5.

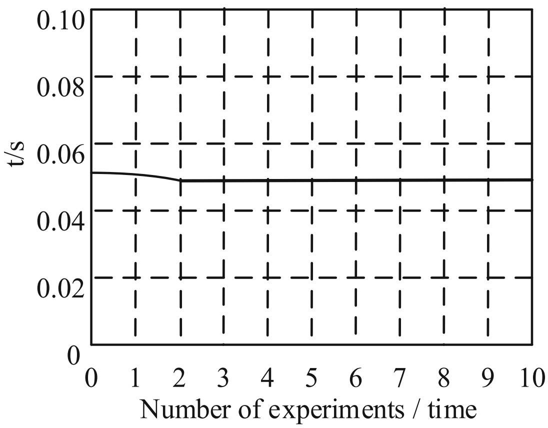

Fig. 5. Load tracking decision changes at 0.05 s

According to Fig. 4 and Fig. 5, it can be explained that in 0.05 s, the input power becomes smaller and the terminal power difference is greater than zero. The controller will give priority to connecting the battery and achieve power balance by charging. Decision changed from “0” to “1”. It can be concluded that the battery of the multi energy complementary power generation system enters into the state of charge when the power difference is near zero.

4 Conclusions

Energy management and load distribution technology is a new technology, which can greatly improve the power efficiency of the power station, and is of great significance to the economic and reliable operation of the power station and the sustainable development of energy. The experimental results show that the multi energy complementary generation can smooth the randomness of single energy, the intermittent fluctuation of energy and the control effect of energy storage, and reduce the impact on the grid, which is very suitable for distributed grid connected operation. The constant voltage control of the dual voltage up and down converter circuit is designed, and the ideal DC bus voltage is obtained, which guarantees the inverter to output high-quality AC current.

Due to the lack of time, there are also many deficiencies in energy management. Some problems and solutions need to be further studied. Therefore, some suggestions and ideas are put forward for the research work in this paper: due to the lack of a large number of field test data, the knowledge base of fuzzy control system can not be trained and optimized by using fuzzy neural network. In the future work, the controller can be modified manually according to the membership function and control rules, so that the performance of the controller can reach a good level.

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