Research on Wind Power Generation and Energy Storage Based on Distribution Network

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Abstract: With the rapid development of the global economy, the large consumption of traditional fossil energy by human beings has not only triggered a worldwide energy crisis. Wind energy, as a clean and renewable energy source, has certain stability. Powering the country through wind power In order to improve its power quality, it can effectively reduce the threat to the overall power grid during the grid connection process. This paper establishes a control model of wind power generation, builds a radiation topology, uses lead-acid battery energy storage, and uses two-way dc / dc conversion the generator is integrated into the DC network and adopts a permanent magnet direct-drive wind turbine. The variable-speed constant-frequency wind power system can control the speed of the wind turbine, so that cp can maintain a maximum value within a large range of wind speed changes, and achieve maximum power tracking control. (mppt).

1. Background

With the continuous progress of human society and the rapid development of the world economy, people's demand for energy has continued to increase. The large-scale exploitation of traditional fossil energy such as oil and coal has accelerated the depletion of non-renewable energy. On the other hand, the large consumption of fossil energy has also increased the concentration of greenhouse gases in the atmosphere, and the greenhouse effect has become increasingly serious. As a result, a series of environmental problems such as climate warming and the deterioration of the ecological environment have occurred worldwide. These problems have seriously threatened the existence of human beings has also restricted the development of the economy to a certain extent [1]. High-tech such as power electronics, new energy, and communications have continued to develop, so that people's requirements for power quality and power supply reliability have gradually increased. The shortage of traditional energy and the problem of environmental degradation continue to intensify. Countries around the world have realized that the use and development of energy must transition from traditional energy to green renewable energy. As a new energy developed and utilized on the basis of new technologies, it has attracted people's attention. .

In recent years, China has issued a series of regulations and documents on new energy, energy conservation and emission reduction, which has promoted the development of China's new energy industry. According to statistics from the National Energy Administration, as of September 2018, China's cumulative wind power grid-connected capacity was 175.92 million kilowatts, newly installed wind power capacity of 12.61 million kilowatts, cumulative average utilization hours of wind power equipment of 1565 hours, and total investment of wind power projects of 34.6 billion yuan. According to the World Watch Institute report: by 2050, China's renewable energy will reach the total energy 40% to 45% of demand. In the near future, an energy pattern in which primary energy is mainly renewable energy and terminal energy is mainly electricity will become a reality [2].

Wind farms produce huge amounts of electricity, and this region cannot fully absorb so much electricity, so the integration of wind power is particularly important [3]. Wind energy itself has strong randomness and uncertainty, which leads to wind energy in the After being converted into electric energy, it will have strong volatility and instability.The integration of small-scale wind power will not have a great impact on the safety of the grid, and may only cause the reduction of

local power quality, such as the occurrence of harmonics. Issues such as pollution and voltage fluctuations. Therefore, an effective wind power model is particularly important.

2. Modeling and control of wind power units

2.1 Types and characteristics of wind power units

There are various classification methods for wind power generation systems. According to the type of generator, it can be divided into synchronous generator type and asynchronous generator type; according to the way that wind turbines drive generators, it can be divided into direct drive type and speed increase. Gearbox driven; another important classification method is to divide the fan into constant frequency / constant speed and constant frequency / variable speed according to the speed of the fan. Among them, the constant frequency / variable speed wind power generation system can be adjusted in real time according to the wind speed The speed of the generator ensures that the generator outputs constant frequency electric power to the grid. The most common power generation systems are doubly-fed wind power systems and permanent magnet synchronous direct-drive wind power systems, as shown in the figure.

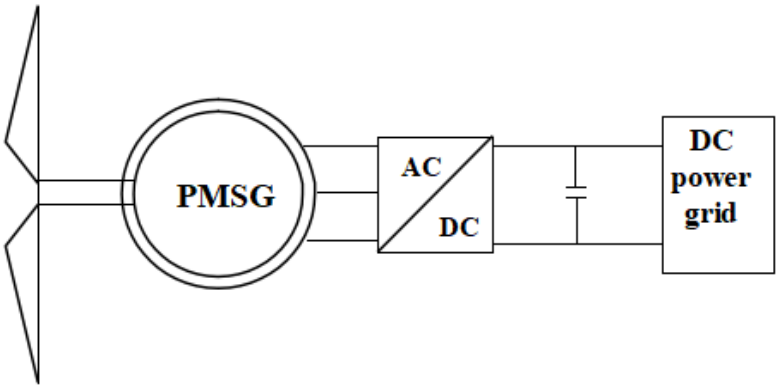

Figure. 1 Permanent magnet direct drive wind turbine

The design scheme of the permanent magnet direct drive unit applied to wind power generation is relatively special. The unit is embedded with permanent magnets on the rotor side, and the wind turbine is directly coupled to the rotor, eliminating the gear box, brushes and current collectors in the traditional electric excitation system. The consumable mechanical parts such as the ring improve the efficiency and reliability of the system, reduce the maintenance work of the wind turbine and reduce the noise. The permanent magnet synchronous generator is directly connected to the power grid through back-to-back pwm converters, making synchronous generator-based The variable-speed wind turbine is completely decoupled from the power grid, and its characteristics are completely dependent on the control system of the frequency converter. In addition, the permanent magnet direct-drive fan has no lower limit on the speed, and the cut-in wind speed is lower. When the generator is still working, the wind energy utilization rate is improved. With the development of power electronics technology and permanent magnet materials, the performance of switching devices and permanent magnets in permanent magnet synchronous direct-drive wind power generation systems has continued to improve and costs have continued to decline. The system has more room for development.

2.2 Topological structure of wind power

The wind power generation model studied in this paper uses a radial topology. The radial structure is similar to the radial structure of the AC power grid, and its topology is shown in the figure below. There is only one main power supply in the system, and many small DC microgrids use the radial type. Topological structure.Although this kind of structure is relatively low in reliability, it is conducive to the control cooperation of fault identification and protection.

2.3 Control model of wind turbine

A wind energy utilization device for a wind turbine, which uses the power of the wind to drive a generator to generate electricity. The wind generates lift when passing through the blades, thereby applying a rotating force to the blades. The rotating blades drag the shaft in the nacelle to rotate, and finally the conversion of mechanical energy to electrical energy, and the operating characteristics of wind turbines not only directly affect the safe and stable operation of the unit, but also determine the energy utilization efficiency of the wind turbine.

According to the aerodynamics of the wind turbine, the kinetic energy of the airflow flowing through the wind wheel per unit time, that is, the wind power formula is as follows:

$$P_{\mathrm{v}} = \frac{1}{2}\rho S v^3 = \frac{1}{2}\rho \pi R^2 v^3 \tag{1}$$

ρ-air density in kg / m ^{3};
S-sweep area of the blade, in m ^{2};
R-blade radius, unit is m;
v-wind speed in m / s.
The expression of the wind energy utilization factor c $_{\mathrm{p}}$ is given by:

$$C_{\mathrm{p}} = \frac{P_{\mathrm{m}}}{P_{\mathrm{v}}} \tag{2}$$

The mechanical power Pm of the wind turbine can be expressed as:

$$P_{\mathrm{m}} = C_{\mathrm{p}} P_{\mathrm{v}} = \frac{1}{2}\rho \pi C_{\mathrm{p}} R^2 v^3 \tag{3}$$

From formula (3), it can be known that the wind energy utilization factor c $_{\mathrm{p}}$ is a characteristic of the wind turbine under the condition of constant wind speed.

An important parameter of efficiency, it determines the amount of mechanical power that can be obtained by a wind turbine blade.

Another important parameter of the force machine is the tip speed ratio λ, which is expressed as:

$$\lambda = \frac{\omega_{\mathrm{t}} R}{v} \tag{4}$$

ωt-the speed at which the fan blades rotate.

cp is a function of the blade tip speed ratio λ and the pitch angle β. From the empirical formula, the wind turbine cp-λ-β can be expressed as:

$$C_{\mathrm{p}}(\lambda, \beta) = (0.44 - 0.0167\beta)\sin\left[\frac{\pi(\lambda - 3)}{15 - 0.3\beta}\right] - 0.00184(\lambda - 3)\beta \tag{5}$$

It can be seen that under different pitch angles β, CP takes the largest value when λ is a certain value. This λ is called the optimal blade tip speed ratio (λopt). Therefore, a variable-speed constant-frequency wind power system can control the wind turbine by Speed, so that the CP can maintain the maximum value within a large range of wind speed change, and realize maximum power tracking control (MPPT).

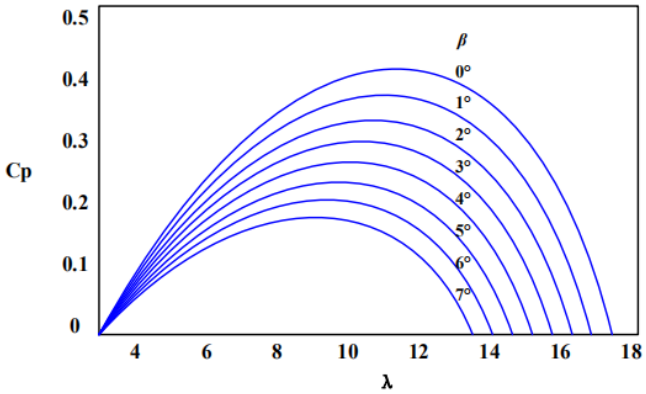

Figure. 2 cp-λ-β characteristic curve of wind turbine

The maximum power tracking operation curve of the variable-speed wind turbine is shown in the following figure. According to the wind speed, the operating range of the wind turbine can be divided into four areas, which correspond to different control methods and tasks. Increased to cut-in wind speed, the wind turbine adopts variable pitch control to make the generator rise quickly and steadily; the AB segment is the maximum power tracking stage, and the maximum wind energy tracking control is implemented. At this time, the wind turbine maintains the state of maximum wind energy capture. For pitch control, the pitch angle β is equal to 0 and Cp = Cpmax is maintained; as the wind speed increases, it will enter the constant speed region, that is, the BC segment. At this time, the wind turbine maintains the maximum allowable speed through variable pitch control. When the wind speed continues to increase, the wind turbine enters the CD section-constant power zone. When the wind speed increases, the wind turbine uses the pitch angle adjustment to reduce the speed. At this time, Cp decreases rapidly, so that the unit power is maintained near the rated value. Do not exceed the limit. When the wind speed exceeds the rated wind speed, the pitch of the wind turbine needs to be controlled to keep its speed and output power below the limit value to avoid the unitLimit Load.

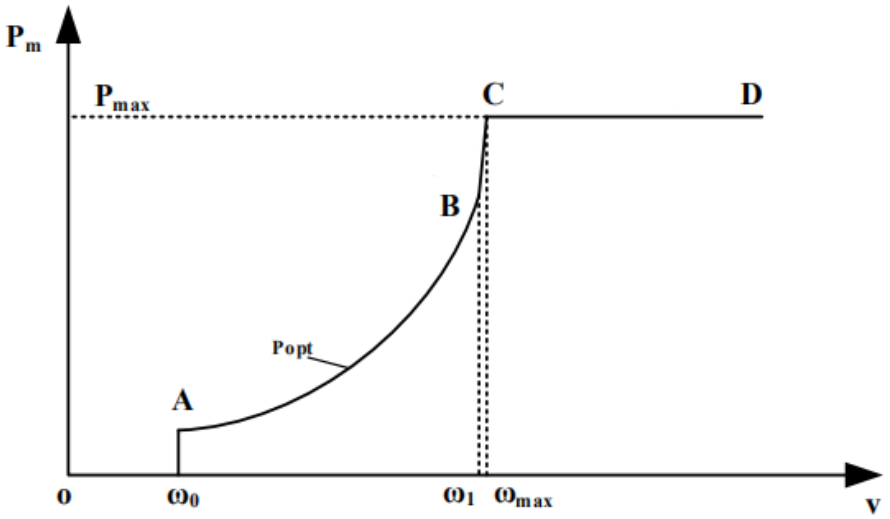

Figure. 3 Power tracking curve and operating area of a wind turbine

3. Energy storage model of wind turbine model

Electric energy can be stored through mechanical, electromagnetic, electrochemical, and phase change forms. Among them, mechanical energy storage includes pumped energy storage, compressed air energy storage, and flywheel energy storage; electromagnetic energy storage includes superconducting magnetic energy storage and super capacitor energy storage. Electrochemical energy storage includes lead-acid batteries, nickel-cadmium batteries, sodium-sulfur batteries, and

lithium batteries; phase change energy storage includes ice cold storage, thermoelectric phase change thermal storage, etc. At present, mainstream energy storage systems in the power grid mainly for flywheel energy storage system, super capacitor energy storage system and battery energy storage system.

Flywheel energy storage system: This system uses a motor to drive the flywheel to rotate at high speed, thereby converting electrical energy into rotating kinetic energy, and using physical methods to achieve energy storage, which has the advantages of wide application range, high efficiency, long life, and no pollution. The energy storage energy density is relatively low, the system is complex, and the requirements for the rotor and bearings are relatively high.

Supercapacitor energy storage system: Compared with general capacitors, supercapacitors have an extremely high dielectric constant, so their capacity is several orders of magnitude larger than general capacitors. Their advantages are mainly reflected in: ① higher power density, It can realize the fast storage and release of charge; ② The charging cycle has a long service life, which can reach more than 10,000 times; ③ High reliability and less maintenance work; ④ It can be used not only in parallel but also in series, thereby increasing the capacity or voltage ⑤Wide temperature range for normal operation; ⑥No environmental pollution, its disadvantage is high investment cost.

Battery energy storage system: The battery is an important energy storage device in the distributed energy storage system. According to different chemical substances, there are many types of batteries, such as lead-acid batteries, nickel-cadmium batteries, nickel-hydrogen batteries, lithium-ion batteries, etc. In recent years, new high-power batteries such as sodium-sulfur batteries and all-vanadium flow batteries have also achieved important technical progress. Compared with the most widely used lead-acid batteries, nickel-metal hydride batteries have greater energy density and higher Power density, can carry out large current charge and discharge, and has better low temperature discharge characteristics, high cycle life and environmental protection without pollution, and its technology is more mature. Therefore, the battery is selected for energy storage.

4. Summary

With the support of various government policies, China's wind power industry has entered an era of explosive growth. Wind energy, as a clean and renewable energy source, has a certain stability. Under the radiation topology, this paper establishes a control model for wind power generation using lead-acid battery for energy storage and applying a permanent magnet direct-drive wind turbine. According to the cp-λ-β characteristic curve of the wind turbine, it can be found that when the wind speed exceeds the rated wind speed, the pitch control of the wind turbine is required to make its speed and output power is kept below the limit value to avoid the unit from bearing the limit load. Through the variable-speed constant-frequency wind power system, the speed of the wind turbine can be controlled, so that cp can maintain a maximum value within a large range of wind speed changes, and achieve maximum power tracking control.

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