Study of wind-solar complementary power system in zhongshan station of antarctic

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Abstract: Due to the environmental and transportation problems caused by conventional diesel power supply of the Antarctic Zhongshan Station, the wind-solar complementary power generation technology can not only guarantee the power supply demand but also protected the environment of the polar regions. Combined with the meteorological data of the Antarctic Zhongshan station and the data of the load electricity consumption, the system energy matching calculation is carried out, which shows that the wind-solar complementary power generation system can meet the load demand of the Antarctic Zhongshan station. Aiming at the extreme polar day-night phenomena and the perennial low-temperature environment, the energy management scheme in Antarctic Zhongshan station are proposed and a Maximum Power Point Tracking control strategy simulation experiment is carried out, the simulation results verify the feasibility of the control strategy.

1. Introduction
The Antarctic Zhongshan Station is one of the major scientific research station set up by China in the Antarctic continent, the Antarctic Zhongshan Station mainly used for real-time monitoring of the Antarctic meteorological elements, and meet the expedition team members engaged in scientific expedition activities and work needs. Therefore, it is of great significance to ensure that the continuous uninterrupted power supply and operation of Zhongshan Station.

Due to the special natural environment and geographical conditions of the polar regions, the transportation of diesel to Zhongshan Station has become the biggest difficulty for expedition teams each year. At the same time, in the process of burning diesel, it emits a lot of carbon dioxide. According to statistics, 1kg of diesel fuel can be completely burned to produce 3.1863kg of carbon dioxide. Therefore, the Zhongshan station power supply system need a suitable clean energy instead of diesel. In Antarctica, wind and solar energy resources are abundant, so, wind-solar complementary power generation system became the Antarctic research station power supply trend.

wind-solar complementary systems research methods are mostly under normal weather conditions to the load power supply and maintain the bus voltage balance. The unique polar day and night phenomenon in Antarctic make it necessary to be powered continuously for at least two months under extreme conditions for the system. The distribution of electricity is also different from the common wind-solar complementary power system inland. Independent large-scale wind-solar complementary power supply system in some islands or remote areas have been used, however, the domestic research on the wind and solar system of the North and South Pole is limited to small system, lack of large-scale power supply solutions for science research stations. This paper fully studies the electricity consumption data of Zhongshan Station provided by China Antarctic scientific expedition team for 3
years, combined with Antarctic scene environment, aiming at the extreme polar day-night phenomena and the perennial low-temperature environment, the energy management scheme in Antarctic Zhongshan station are proposed and a Maximum Power Point Tracking control strategy simulation experiment is carried out, the simulation results verify the feasibility of the control strategy.

2. Antarctic Zhongshan Station Wind-Solar Complementary System Structure

The wind-solar complementary power generation system in Zhongshan Station of Antarctic mainly by the photovoltaic power generation subsystem, wind power generation subsystem, wind-solar complementary control subsystem, battery pack, load five parts.

Photovoltaic power generation systems and wind power generation system produce power into the wind-solar complementary control subsystem, the system provides stable power to polar regions. In order to prevent the photovoltaic power generation subsystem and wind power generation subsystem is not working when the battery is reverse charging, its need to set in the branch has a sufficiently large anti-charge current and very small reverse saturation current anti-backfill diode. In addition, need unloading circuit and brake circuit as a wind power subsystem protection device. Battery is energy storage device, the excess output of the photovoltaic power generation systems and wind power generation system be stored, in case of wind, light resources insufficient to ensure normal load power, at the same time to provide a stable power to the control subsystem and other modules and maintain a constant bus voltage to ensure system stability. The wind-solar complementary system of this study is mainly used to power the AC load, therefore, the control subsystem output power through the inverter subsystem into AC power for the load.

3. System energy matching calculation

This paper select the 10kW wind turbine, start up wind speed is 3m/s, Rated wind speed is 10m/s. Check the relevant information can know Antarctica average wind speed in July is 7.73m/s, wind turbine can not maintain the rated state of long-term operation. At the same time, the output of the wind power generation part depends not only on the installed capacity of wind turbines, but also is closely related to the local wind energy resources, altitude and temperature. Therefore, the need for specific calculation of wind turbine power generation.

\[
Pg = \frac{1}{2} C_p \rho S v^3
\]

(1)

\[
P_g \text{— Actual wind turbine shaft power, W; } \rho \text{— The corrected air density, kg/m}^3; S \text{— Wind wheel sweep area, m}^2; v \text{— Wind speed, m/s; } C_p \text{— Wind energy utilization factor, the limit is 0.593}
\]

\[
\rho = \rho_0 \frac{1}{1 + 0.00366(\frac{t - 378}{100})}
\]

(2)

\[
\rho_0 = 1.293 g/L, \ t \text{ is temperature, } P_y \text{ is Zhongshan station pressure.}
\]

\[
W = W_g h
\]

(3)

\[
W \text{— Power generation, kW·h; } P_g \text{— Shaft power, KW; } h \text{ is hours}
\]

This paper selects 20 wind turbines. In order to guarantee the normal power supply under the worst conditions, the monthly power generation of the wind turbine from April to August is calculated as shown in Table 1. It can be seen that only in April the wind turbine can not meet the load demand, at this time the lack of electricity from the battery can be added.
Table 1 April to August wind power generation capacity

| Month | Wind speed /m/s | the monthly power generation/kW·h | load/kW·h |
|-------|-----------------|-----------------------------------|-----------|
| 4     | 6.91            | 63452                             | 70246     |
| 5     | 8.15            | 104558                            | 82049     |
| 6     | 7.62            | 85450                             | 81036     |
| 7     | 7.73            | 89208                             | 87743     |
| 8     | 7.85            | 93435                             | 82938     |

Zhongshan Station have adequate wind resources the whole year, the wind-solar complementary power generation system is based on wind power, solar power and supplemented by batteries. Considering the influence of Natural Conditions, Geographic Latitude, Atmospheric Transparency and Altitude on Power Generation Efficiency of Solar Panels [6], the final selection is 300W solar panels composed of 400 PV arrays for solar power. Solar panel conversion efficiency is 18%, the area is 1956mm × 992mm, the PV cell unit area of radiation is about 1570MJ in polar day, the PV array produced 52641kW·h per month. During the polar day, load less power consumption, at this time only need to put two wind turbines to meet the load requirements. This shows that monthly power generation can fully meet the load requirements.

4. Antarctic Zhongshan Station Wind-Solar Complementary System Control Strategy
Maintaining the balance between power generation and power consumption is a necessary condition for the operation mode of wind-solar complementary power generation system. The battery as the most important part of the entire system presents two states: the nature of the load during charging, the nature of the power during discharging. When the wind and solar energy is not enough, that is when their sum is less than the reference power, the battery has been discharged. In contrast, when their sum is more than the reference power, the battery has been charged. Due to changes in external conditions is not artificially predictable, therefore, the power generated by the wind-solar complementary power generation system and the power consumed by the load fluctuate. The climatic conditions are divided into three situations: normal weather, Polar night, Polar day. Three cases of energy management as shown in Figure 1

![Fig.1 Energy management under three weather conditions](image-url)
When polar night, 20 wind turbines all put into use, battery and wind resources together to the load power supply. When polar day, light intensity sufficient, wind turbines only need to invest 2 units, at the same time can be other wind turbine maintenance. In normal weather, the wind turbines all put into use, PV arrays and wind turbines together to the load power supply, the excess power to the battery charge to ensure that the battery can be used as backup power in the extreme weather complementary wind-solar complementary power generation system.

In any weather conditions, it need to determine whether the wind turbines and PV array output voltage can meet the minimum voltage of step-down circuit. At the same time the voltage can be used for maximum power tracking. The control strategy is mainly based on the following three situations: both have light and wind, weak wind and adequate light, weak light and adequate wind. Compare the difference between resources output power and load power. If the difference is greater than 0, then the wind and solar energy enough to meet the load power supply, after that check whether the battery is fully charged, if full power is unloaded, if it is not satisfied, extra power charge to the battery. If the difference is less than 0, then the wind and solar energy not enough to meet the load, after that the battery discharges to the load with the wind and solar energy to share the load needs.

5. Control Strategy Simulation

5.1 MPPT Strategy Simulation of PV Cells
Photovoltaic power generation system MPPT control strategy included Disturbance observation method, Incremental conductance method, Constant Voltage method, blury logic control method, Neural Network Control Method. In this paper, use the adaptive variable step disturbance observation method for MATLAB simulation. PV cell parameters are $U_{oc} = 34.95\, V$, $I_{sc} = 9.26\, A$, $U_{m} = 27.5\, V$, $I_{m} = 8.59\, A$, Rated power is 300W. The above parameters are measured under standard Conditions ($T = 25^\circ C$, $S = 1000\, W/m^2$, $AM = 1.5$). Select Zhongshan Station annual average temperature is $-20^\circ C$, simulation diagram shown in Figure 2.

![Simulation Diagram](image)

Figure 2 shows the simulation results, it can be seen that the light intensity is 1000W/m² in the first 2s, the output voltage of PV cells is about 34V, 0.95 V lower than the 34.95 V for the standard state. Output power is about 290W, 10W lower than the 300W for the standard state. This is because the
output power of PV cells is affected by temperature. The lower the temperature, output power will be reduced, therefore, the efficiency of PV cells will decrease because of the polar in a low temperature environment the whole year.

Fig. 3 300W PV cell temperature changes in the same light intensity simulation results

From Figure 3 we can see: although the initial voltage and power output fluctuations, but the response speed is better, the voltage and power can be stabilized in 0.07s basically. Light intensity changes suddenly in 2s and 4s, respectively from 1000W/m$^2$ to 800W/m$^2$, from 800W/m$^2$ to 600W/m$^2$. At this time, the voltage and power also change, it can track the new work point and maintain the maximum power output basically within 0.05s. Indicating that the strategy can quickly track the response in the polar cold environment, and the output efficiency is also higher. It can supply power to load steadily with the highest output power.

5.2 MPPT Strategy Simulation of wind turbines

Wind turbine power generation system MPPT control strategy included Tip speed ratio method, Power signal feedback method, Mountain climbing search method, blurry logic control method. In this paper, use the variable step climbing search method for MATLAB simulation. 10kW wind turbine parameters are: rated wind speed is 10m/s, rated power is 10kW, the maximum wind speed does not exceed 50m / s, stator resistance is 0.0169 $\Omega$, rated rotating speed is 100r / min, wind wheel radius is 4m. As the altitude is higher, the air density is lower, it will affect the utilization rate of wind energy. Access to relevant literature[5] and calculated can know when the Zhongshan Station altitude is 3600m, the air density is about 0.927kg / m$^3$. Take these values into the wind turbine simulation model for simulation, simulation diagram shown in Figure 4.
In order to more realistic simulation of the scene environment, we build natural wind speed module then input wind turbine model[6]. Simulation results shown in Figure 5: from the simulation it can be seen that the wind speed is low in the first 4s. As the wind turbine start wind speed is 3m/s, therefore, the corresponding output power is also very low. Wind speed increases in 4s ~ 8s, the maximum wind speed is 17m/s at 6s, the corresponding output power also increases. At this time wind turbine into a stable operation period, the maximum output power is 13KW. Wind speed decreased in 8s ~ 12s, the power also decreased. Under standard conditions, when the wind speed is 10m/s, it should output 10kW power. The actual output power is about 8.2 kW because of the influence of air density on wind energy utilization rate.
Fig. 5 Simulation results of natural wind speed

Although the wind speed, output power and wind turbine speed changes are larger, but the response speed is better, power output and speed curve can increase or decrease with wind speed within 0.02s basically. Figure 6 simulates a sudden change in wind speed, it can see the response speed clearly. The power and rotating speed can track the maximum power output within 0.14s at start up, each mutation can also be stable work within 0.1s to a new point.

Fig. 6 Simulated results at abrupt wind speed

From the above analysis we can see: due to the environmental impact of Zhongshan Station, wind energy utilization rate will decline, the actual wind turbine output power does not reach the ideal
state, therefore, we should consider this factor when determining the number of wind turbines. But the system tracking is faster, in the case of severe natural winds also can quickly stabilize the new operating point output power. It is proved that this strategy is feasible in the Antarctic Zhongshan Station.

6. Conclusion
In this paper, based on the special environment of Antarctica, the energy management scheme and control strategy of wind-solar complementary power generation system are proposed and the MPPT control strategy of PV subsystem and wind power subsystem is simulated. Simulation results show: MPPT control can be quickly tracked within 0.15s to the maximum power point. The output power of the PV array is affected by the low temperature of the polar regions are decreased. The output power of the wind turbines is affected by the Antarctic high altitude and low air density are reduced. The simulation results show that the monthly power supply of wind turbine and PV array can meet the load demand of Zhongshan Station.

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