The nacelle cooling system design based on Sinovel1500 wind turbine

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Abstract. The paper presents a nacelle cooling system of Sinovel1500 wind turbine to reduce the temperature in the nacelle. For solving the high temperature limit the output problem of Huarui sl1500 after long time operation. The system uses the upwind characteristics and motion characteristic as the operation principle. And chooses the typical models, make three groups and control the parameters in experiment. Contrast the different experiment result can effectively reduce the nacelle temperature, which can ensure the optimum power output. And verify the reliability of the nacelle cooling system and keep high operation efficiency.

Keywords: The nacelle cooling system; the windward hood; limited power output; oil cooling fan.

1. Introduction

The environmental issues have affected people's lives to a certain extent. Our country has presented a project to deal with the fog problem, reduces the thermal power proportion less than 65% by 2017 [1]. Under this circumstance the wind power industry has favorable conditions for development, it's become more important to keep the wind farm generation stable [2]. If high temperature inside the nacelle cannot be control, the wind turbine may happen limited power output phenomenon, even stop. Nowadays there is no proper project for wind farm to solve the high temperature in the nacelle. Traditional solutions, open the tower door, escaped plate and skylight cover plate, have little effect and also bring potential hidden trouble. This paper provides a design focuses on solving the ventilation of nacelle with using aerodynamic principle, make the air inside the nacelle form a powerful internal air convection which design to reduce the nacelle temperature. This design does not need additional power plant, greatly reduce the cost.

Sinovel1500 model wind turbines occupies most of the market share in domestic double-fed wind turbine market [1]. Sinovel1500 machine as example, after working 3 to 5 years, the working efficiency of the gear box and generator are significantly lower. It's acknowledged that in a closed nacelle the internal circulation of air cannot work and lead the temperature rising, the heat exchange ability of the gear box declines, the filtering plate temperature is too high, finally lead limited power output, even cause outage [2]. Under the weather conditions of high temperature and strong wind, because of the high oil temperature, the turbines often happen the limited power output and downtime, and all of this are definitely influence the service life of turbines and power generation, which would brought huge economic losses to the wind operators [3]. In order to solve the problem that high temperature inside the nacelle lead to high oil temperature of gear box, and this problem could bring about the technical challenge limited power output. In this industry has not a kind of lower cost and high efficient solution. Traditional wind farm maintain measures mainly opened the door, escape hole and skylight cover plate, while all these measures have little effect, also might bring potential hidden trouble. This paper presents the design focuses on solving the problem of nacelle ventilation by using the aerodynamics principle, make the wind inside the nacelle form a powerful internal air convection to realize the designed target bring down the temperature inside nacelle. The design does not need additional power plant, greatly reduce the design cost.

2. Nacelle air heat exchange theory

With the increase of output power, gear box calorific value increase, oil temperature increase, and bring about the nacelle into a vicious cycle of higher level. So control the temperature inside the nacelle has important significance. The gear box generated heat principle as shown in formula (1), P is transmission power input.

$$Q = 3600(1 - \eta)P \tag{1}$$

According to the conservation of energy, unit time the heat energy gear box produced equals the heat of radiator [4], so the heat energy expressed as formula (2).

$$Q_1 = cm(t_2 - t_1) \tag{2}$$

The calorific value of gear box is the air exchange in the nacelle, and unit time the calorific value of gear box is as formula (3).

$$Q_2 = 45 \times \text{t KWh} \tag{3}$$

When $Q_1 = Q_2$, the exchange air of nacelle is the air volume of normal wind turbine heat exchange, as formula (4).

$$Q_1 = cm(t_2 - t_1) = c\rho V_1(t_2 - t_1) = Q_2 \tag{4}$$

Wind generator can get heat exchange volume V_1=25613m^3 .And the theory of oil cooling fan air volume is V_2=32000m^3 /h, $V_1 < V_2$, so V_1 meet the basic requirements of oil cooling fan air volume. Wind farm need to exchange the air volume per hour is 25612m^3, and it can basically meet the principal capacity, while as the growth of wind turbines running time, the efficiency of gear box and cooling capacity of oil cooling system is decreased, and it couldn't satisfy the gear box cooling requirements.

3. The overall design scheme

Under the premise of keeping the original structure, the nacelle cooling device set an windward hood outside the escape door, which form convection air duct with the upside nacelle. And the opening direction of windward hood is always towards the hub windward side.

The nacelle cooling system also has a safety mesh cover installed outside the escape door, and the safety cover has grid. , the windward hood is connected to the nacelle fixed by bolts, and upside the nacelle installs a air guide sleeve, which opening end back to the windward side.

Setting a rope at the bottom of windward hood, and the rope end fixes under the windward hood by bolts, another end is connected to main frame inside the nacelle. The principle diagram of nacelle heat dissipation is shown as figure 1.

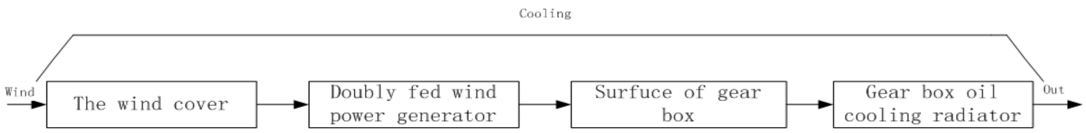

Fig. 1 The principle diagram of nacelle heat dissipation

To reduce the nacelle temperature and keep the optimized power output, traditional cooling method is to add axial flow fan on the nacelle backend, and use it to realize the analyze the inside and outside air exchange. As the interior environment, the air circulation isn't very well inside the nacelle, and cooling effect is not obvious and consumes the energy. So we know increase the axial flow fan make the maintain operation inconvenience.

This design is different from traditional cooling technology, equipped with the windward hood in the exit parts. According to the air convection principle, wind blow from windward hood into nacelle end, and the cooling path is shown in Fig.1. Cold air outside flows from generator, inverter and gear box, eliminates the heat energy. Because hot air has small density, when the hot air gathers at the top of nacelle, discharged by nacelle opening end, this process makes the air form convection. The windward hood is always toward the windward side, its model is shown in Fig.2.

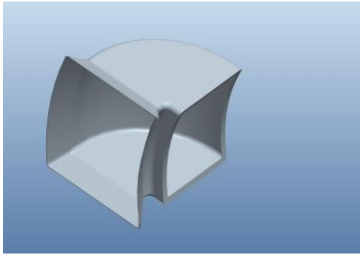

Fig.2 The model of windward hood

Air guide sleeve is on the upper surface of nacelle, and back opening the hub windward surface. This way can protect the machine from rain and snow weather, and form better air duct to protect machine. Through rope the windward hood bottom connects with mainframe to guarantee the stability of windward hood when suffered significant chronological wind speed.

The principle system design is shown in figure 3. Among them, 1-the windward hood; 2-air guide sleeve; 3-gear box; 4-generator; 5-escape exit; 6-hub; 7-open; 8-rope; 9-mainframe; 10-nacelle shell. 1 is set outside of 5, and form air duct with 2. The opening side of 1 is windward to 6, and 2 is back to 6. In order to protect the exit, the 1 mouth edge should be smooth round corner [5].

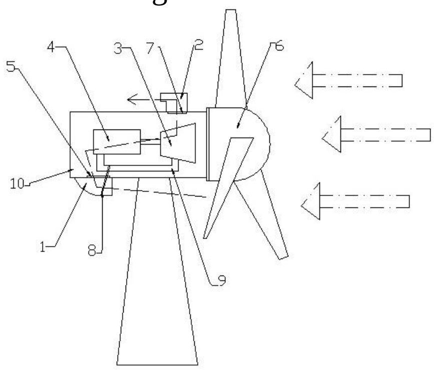

Fig.3 The structure diagram of nacelle cooling device

4. The simulation result

Tab.1 The experiment parameter contrast of Sinovel1500

The windward hood data statistics							
V m/s	S1 m2	F N	S2 m2	M	N	W1 KWh	W2 KWh*103
3	1.522	8.39	274	9	6	52.8	1900
4	1.522	14.92	365	11	8	52.8	1900
5	1.522	23.31	457	14	9	52.8	1900
6	1.522	33.56	548	17	11	52.8	1900
7	1.522	45.68	639	20	13	52.8	1900
8	1.522	59.66	731	23	15	52.8	1900
9	1.522	75.51	822	26	17	52.8	1900
10	1.522	93.22	913	29	19	52.8	1900
11	1.522	112.80	1005	31	21	52.8	1900
12	1.522	134.24	1096	34	23	52.8	1900
13	1.522	157.55	1187	37	25	52.8	1900
14	1.522	182.72	1278	40	26	52.8	1900
15	1.522	209.75	1370	43	28	52.8	1900
16	1.522	238.65	1461	46	30	52.8	1900
17	1.522	269.41	1552	49	32	52.8	1900
18	1.522	302.04	1644	51	34	52.8	1900
19	1.522	336.53	1735	54	36	52.8	1900
20	1.522	372.51	1826	57	38	52.8	1900

This design uses Sinovel1500 unit as the research object, the nacelle volume is $52m^3$ the windward hood mouth section area is $1.5m^2$ 2.2KW parameters of axial flow fan is 10000 m after/h, compared with current factory technical improvement scheme under different wind speed and the nacelle ventilation rate, save power contrast are shown in table 1.

V expresses wind speed. S_1 expresses windward area, *F* expresses stress. S_2 expresses supply air per minute. M expresses nacelle change air per minute. N expresses the equivalent of each 2.2KW axial flow turbine. W_1 expresses one turbine saved electricity one day. W_2 expresses 30000 wind farm saved electricity one year.

In order to verify the installation of windward hood if can reduce the nacelle temperature and gear box temperature, select 1# wind turbine as experimental unit, contrast with own data after the technical transformation.

Manufacturers and technical plan after the transformation of the unit 2# and no high temperature limit power phenomenon of excellent unit 3#, respectively from the cabin temperature, gear box oil temperature under the condition of different wind speed data parameters were compared.

1# wind turbine contrast with manufactures technical transformed 2#, worked well without limited power output 3#,and got the simulation result as Fig.4,Fig.5,Fig.6 shown.

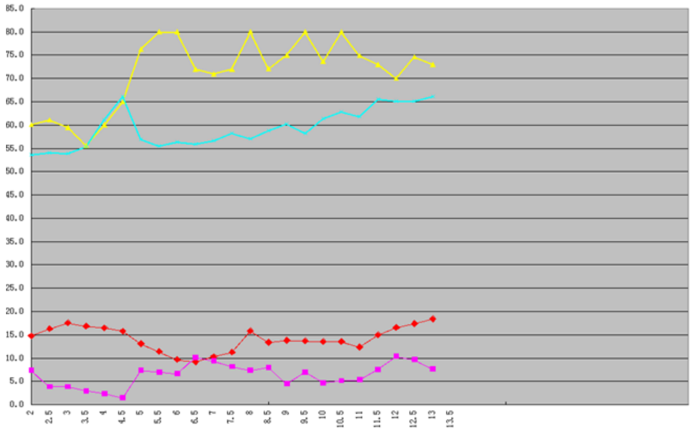

Fig.4 1# before and after comparison chart

In Fig.4, the red line representatives the temperature before modification, the pink line representatives the temperature after modification, the yellow line representatives the temperature of gear box oil before modification, the blue line representatives the temperature of gear box oil after modification. We can obtain the conclusion by compare the data before and after modification that the average temperature inside the nacelle is 15℃ higher than the external environment, while the average temperature inside the nacelle after modification is 5℃ higher than the external temperature environment and with the increase of the wind speed the temperature is decrease. The gear box oil temperature before modification is 75℃. Its highest temperature is 80℃ (the limited power temperature is 75℃, and the downtime temperature is 80℃).

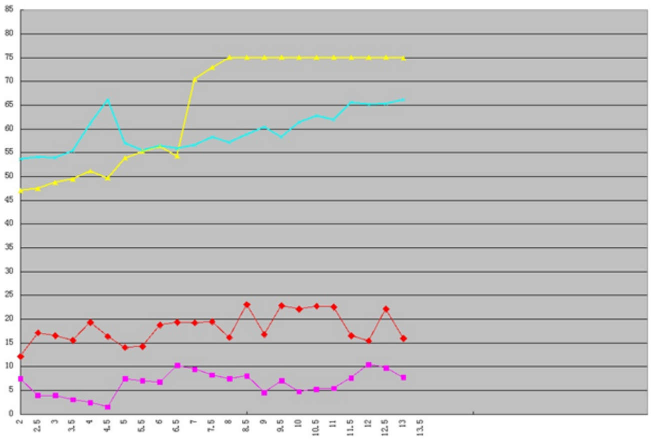

Fig.5 The contrast data diagram of 1# and 2#

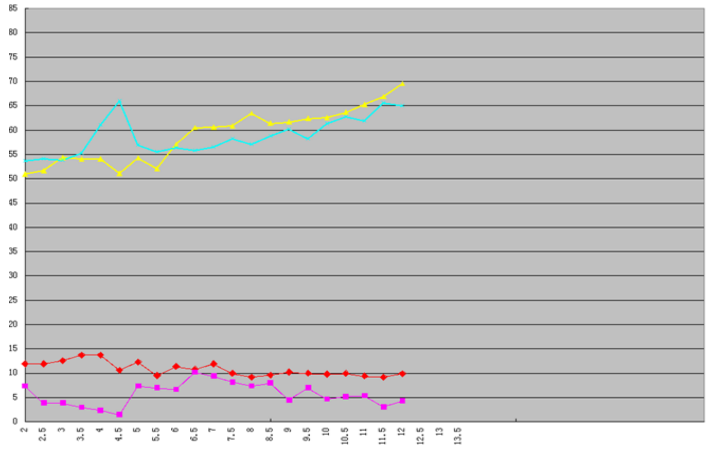

Fig.6 The contrast data diagram of 1# and 3#

Through the technical modification, the oil temperature of gear box could keep 60℃, and with the increase of wind speed, the temperature is stable to realize the full-power operation. Comparing Fig.4 and Fig.5, conclude that the 1# average temperature difference is 5℃ and 2# is 20℃, so we know that 2# unit temperature did not go down after modification, the traditional method did not work well, while the nacelle cooling system has a better performance. Based on Fig.6, compared the data of 1# unit with the data of 3# unit, the red line shows the average temperature of nacelle is about 11℃, with the increase of wind speed the temperature difference between the internal nacelle and external environment is more and more big. All this shown that the cooling ability of nacelle is certain. The pink line shows that 1# turbine has good performance for cooling and ensures the wind turbine work in full power output in high temperature and high wind.

5. Conclusion

The paper proposes a nacelle cooling system to solve the problem of operation long-term caused high temperature internal nacelle, by select typical unit group to contrast the different turbines cope with the high temperature internal the nacelle. The simulation shows the system of nacelle cooling has a very significant effect and also has a good effect on decreasing the oil temperature of gear box. So this nacelle cooling system based on Sinovel1500 is an effective measure, the design is scientific and reasonable, it also deserve to generalize.

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