UDC 620.92

REDUNDANT CONTROL METHOD FOR YAW OVERLOAD PROTECTION OF WIND TURBINE

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This article first describes the yaw control method of the wind turbine, then analyzes the yaw control strategy of the wind turbine, and finally discusses the reasons for the yaw overload and the redundant control method of overload protection.

Introduction. By the redundant control of the yaw overload protection, extreme wind conditions can be effectively avoided. After the yaw system returns to normal, the yaw can ensure the continuous power generation of the wind turbine. At the same time, the fault shutdown will be performed when the wind direction deviation is large. To ensure the safety of wind turbines verified by the wind farm, the yaw overload redundancy control method can effectively protect the yaw equipment, reduce the number of downtimes, increase power generation revenue, and reduce operation and maintenance costs [1].

Yaw control method of wind turbine. *Rudder steering and yaw control device (Passive wind yaw control).* This yaw control method belongs to passive yaw to the wind, and its steering device is a tail rudder that makes the wind-facing surface of the wind turbine always face the direction of the incoming flow through the tail rudder swinging with the wind. Most of these wind turbines are small wind turbines, similar to the wind measurement towers used in weather stations, and the area of the tail rudder and the swept area of the wind turbine must reach a certain degree to meet the accuracy of wind. The characteristic of this yaw method is that it does not require electric or manual control.

Side wind wheel direction adjustment device (Passive wind yaw control). This kind of steering device is to install 1 to 2 small wind wheels on the side of the nacelle. The steering axis of the fan is perpendicular to the main shaft of the wind wheel. When the wind direction deviates from the main wind wheel, the side wind wheel will be blown by the wind, and the nacelle is rotated through the worm gear mechanism until the wind direction is perpendicular to the side wind wheel axis. This yaw device requires that the inclined position of the side wind turbine blades must enable the nacelle to rotate in the correct direction. The side wind wheel direction adjustment device can be used for wind turbines in the upwind direction and in the wind turbines in the downwind direction. The advantage of the wind wheel against the wind is the torque connection between the nacelle and the tower, and the yaw moment of the nacelle does not produce torque vibration excitation. The disadvantage is that when the speed of the wind wheel is high, the load is increased due to the gyro moment.

Active wind yaw control. Active wind yaw control, also known as automatic wind yaw control, mainly uses external wind speed and direction sensors to collect wind speed and wind direction signals, after it calculates the deviation angle, then it uses an electric or hydraulic drive device to make the nacelle according to the required yaw angle and the direction is deflected. This control method is more suitable for large-scale megawatt wind turbines.

The active (electric) yaw system generally includes a wind vane that senses the wind direction, a yaw motor, a yaw star gear reducer, a yaw counter, and a twisted cable alarm device. Its working principle is as follows: the wind speed and direction sensor send the collected signal to the main control system of the wind turbine, and after processing by the controller, it sends a clockwise or counterclockwise rotation command to the yaw motor. Generally, in order to reduce the gyro torque during yaw, the motor after the speed is decelerated by the gearbox, the yaw moment is applied to the large ring gear of the slewing body to drive the wind wheel to yaw against the wind. After the wind is completed, the controller sends a stop command and the yaw process ends. In addition, this type of wind turbine must have the ability to protect the yaw torsion cable, have a yaw counter to record the total deflection angle, and automatically untwist the cable when the limit of the twisted cable is reached.

Wind turbine yaw control strategy. *Weather vane control method.* The current mainstream yaw control technology is mostly a control method based on wind direction sensor (wind vane), also known as VC control, which detects the direction of the incoming wind and wind through a mechanical or ultrasonic wind direction sensor installed at the tail, and sends the signal to the main control. The system calculates the deviation between the current cabin position and the wind direction through the main control system, and then outputs a yaw angle signal to the yaw actuator to achieve yaw control. The traditional VC yaw control method is characterized by simple control technology, strong practicability, low maintenance cost, and can basically meet the yaw control needs of large and medium-sized wind turbines in terms of wind accuracy.

Power control HC algorithm. Although the traditional wind vane control and yaw control method is simple, but due to the influence of wake and wind turbulence, the accuracy of the wind needs to be improved. When the wind direction difference is ±15°, the wind vane will fail to distinguish the wind, and the wind direction sensor is used as the method of distinguishing wind is not efficient.

Compared with the traditional algorithm of power control, the HC algorithm improves the utilization rate of wind energy from the perspective of power maximization. At the same time, due to its reasonable absorption of wind load, it also increases the mechanical life of the wind turbine.

Improved V-HC algorithm program design. Although the HC algorithm can track the best power value, when distinguishing the direction of rotation: first, turn it counterclockwise or clockwise. Then see whether the direction is correct according to the power change. This step requires a long distinguish time and running time for large MW-class wind turbines.

When the wind speed is lower than the rated wind speed, the wind speed change is more complicated, and the HC algorithm is applied within ±5°:

1) When the wind direction difference is greater than 15°, start the yaw, calculate the yaw direction according to the wind direction signal given by the wind vane and the current cabin position, and control the wind turbine to move in the windward direction;

2) During the yaw process, compare the feedback value of the cabin position with the wind direction signal. When the difference is less than 5°, record the power change and monitor the wind speed change. Set the calculation step to 1s.

When the wind speed is greater than the rated wind speed, the wind is higher, the airflow is relatively stable during the movement, and because the power has reached the rated power, the maximum power point can no longer be tracked. At this time, the HC algorithm is no longer needed, and the VC can be used to control the yaw. Meet the wind requirements of the unit [3].

Reasons for yaw overload. Yaw overload protection is an active power-down protection for the yaw motor protection which can effectively prevent the temperature of the yaw motor winding caused by overload, overcurrent, etc., which reduces the winding insulation life and reduces the service life of the yaw motor. Common causes of yaw overload failure include poor lubrication of the yaw bearing, high yaw pressure, and dust accumulation on the brake disc. These are all external causes, and the yaw overload is allowed; when designing the yaw system is often ignored.

Theoretically, the maximum drive torque of the yaw motor should envelop the maximum external load required by the yaw process during the design of the whole machine. Define the maximum load required for this requirement as the cut-off load. When each complete machine manufacturer designs a wind turbine, the calculation method of the cut-off value of the external load may not be consistent, but it is generally not defined as the ultimate load in the full life cycle of the wind turbine. This is because the ultimate load is the maximum load experienced during the entire life cycle of the wind turbine. The ultimate load lasts for a short time and is a load that occurs once in several years. If the maximum driving torque of the yaw motor is required to envelop the limit load, it will cause conservative selection of the yaw motor which reduces the economy of the equipment.

Take the evaluation of the driving capability of the yaw system when a certain type of wind turbine is yaw as an example. The driving capability of the yaw system is considered to be able to successfully execute the yaw by overcoming 99% of the external load, and less than 99% of the external load It may cause an unstable state. Therefore, when the wind turbine generator yaws, there is a certain probability that the yaw drive capacity is insufficient which leads to the overload protection of the yaw motor.

In summary, when selecting the yaw motor, considering the economy of the overall system, the yaw system in the simulation design is not 100% successful in performing the yaw action, so it is necessary to study how to control the yaw overload protection redundantly [2].

Yaw overload protection redundant control method. In order to reduce the occurrence of yaw overload protection, it is proposed that when extreme working conditions cause the yaw motor protection switch to trip, the yaw stop action should be executed immediately. At this time, although the yaw motor protection switch trips, it does not affect the safety of the unit, and the wind turbine can be shut down without failure. By using hardware self-reset and software logic control to yaw again, extreme working conditions can be avoided.

There are two main types of protection for yaw motor: motor protection switch and thermal relay. After the motor protection switch is tripped, it must be closed manually. It is not suitable for use and can be changed to a thermal relay with self-reset function. The working principle of the thermal relay is that the current flowing into the thermal element generates heat, which causes the bimetallic strips with different expansion coefficients to deform. When the deformation reaches a certain distance, it pushes the connecting rod to break the control circuit, thereby making the contactor. When power is lost, the main circuit is disconnected to realize the overload protection of the motor. With disconnection of the current, the temperature of the metal sheet gradually decreases. When it is completely cooled, the metal sheet returns to its original shape and the thermal relay is automatically closed. At this time, although the thermal relay has been automatically closed, the wind turbine generator has executed the yaw stop command when the thermal relay is tripped, and the yaw motor circuit will not be turned on again due to the closure of the thermal relay. The parameters "Yaw failure times (C1)" and "Yaw failure waiting time (T1)" are added to the control. By setting the two parameters differently, diverse decisions of yaw failure can be made. The parameter "Thermal Relay Recovery Waiting Time (T2)" is added to the control to reduce the failure rate of restarting the yaw by fully considering the heat dissipation of the thermal element of the thermal relay.

Conclusion. Research on the redundant control of the yaw overload protection using the control loop of the yaw soft start is of great significance for improving the availability and power generation time of wind turbines. This article comprehensively elaborates the yaw loop hardware scheme and software scheme, and verifies it according to the usage of the wind farm.

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