The Technical to Realize Variable Speed Constant Frequency Operation of Large Wind Turbine Generator

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Abstract. In this paper, through the introduction of the existing various mainstream wind turbine model, understand all kinds of operation mode and control method of wind turbines, contrast to put forward all kinds of wind turbine operation mode and control methods of the advantages and disadvantages, comprehensive put forward more effective technology of large wind turbines to realize variable speed constant frequency operation method, as well as for large wind turbines to realize variable speed constant frequency technology methods of the future.

Introduction

With the traditional energy sources, such as coal, oil, step by step to dry up, improve the utilization of renewable energy become more important, Wind power generation technology is one of the most mature technologies, which has the most mature technology and the prospect of commercial development[1]. In order to better use of wind energy, improve the stability of the wind power, guarantee the safety of power grid operation, we need more reasonable and effective technical methods of large wind turbines running, realize the stable operation of the wind turbines.

The overall capacity of all wind turbines installed worldwide by the end of 2017 reached 539’291 Megawatt, according to preliminary statistics published by WWEA. 52’552 Megawatt were added in the year 2017. In 2017, the installed capacity of offshore wind turbines will reach 3.3GW, and all the installed capacity will be close to 17 GW, and 7.9 GW is still in the pipeline. China's wind energy utilization has a large proportion in the world, and it has been devoted to the study of wind energy utilization. The by far largest wind power market China installed an additional capacity of 19 GW, and continues its undisputed position as the world’s wind power leader, with a cumulated wind capacity of 188 GW[2].

Existing Wind Turbines Technology

Wind turbine technology is one of the key technologies that affect wind energy utilization. As the main equipment for collecting and converting wind energy, it is important to understand its key technology to improve the efficiency of wind energy utilization. By the type of generator used in wind turbine and the mode of operation with grid, wind turbines can be divided into the following:

(1) Constant speed wind turbine

Figure 1. Constant speed wind turbine.
Constant speed wind turbine model is shown in figure 1, the generator rotor through the shaft connected to the wind wheel, and the generator stator circuit connected to the power grid with ac line. The existing Constant speed wind turbine are usually connected to the power grid by a squirrel-cage rotor (4/6 two-speed asynchronous generator) through the soft start-up process. The rotating speed at the 50Hz power grid frequency is 1500/1000 r/min. From zero power to full rated power, the motor only works at high and low speeds, and when the power grid frequency is stable, the range of motor speed changes is less than 2% at each working speed. The wind turbine electric control system is equipped with the corresponding automatic switching capacitor, bank to perform reactive compensation.

(2) Slip difference control variable speed wind turbine

Wind turbine’s type of generator USES the wound rotor type asynchronous generators, on the rotor connecting a set of small power electronic device to control the wires of a rotor current, and by adjusting the generator rotor current is to change the characteristic curve of torque and rotational speed of asynchronous generator, so as to adjust generators turn slip, further change the speed, the wind wheel speed to follow the change of wind speed and wind power to achieve high absorption rate[3].The speed regulation range of this kind of variable speed can only be above the synchronous speed of the generator, the wind energy utilization rate is slightly higher than the constant speed wind turbine, and the output current of the rotor is consumed in place and cannot be taken to the power grid for utilization. The generator itself cannot adjust the reactive power, and it still needs to add the supporting cast capacitor bank. Due to the variable flow unit rotate together with the rotor, the volume is small, but poor reliability and maintenance features, the early part of the wind turbines using this technique, in domestic has a certain capacity in the operation of this wind turbine.

(3) Doubly-fed variable speed wind turbine

Wind turbines uses a doubly fed asynchronous generator (DFAG), generator types are adopting rotor winding asynchronous induction generator, the stator coil directly connected into the power grid, the rotor three-phase coil current through the connection after three slip ring lead to a power electronic converter device, and different from the slip difference control variable speed wind
turbine is the rotor side converter by the dc bus through a set of PWM rectifier unit connected to the
grid, it can adjust the generator speed in a wind range near the synchronous speed, and in a very
wide range of wind speed change, wind turbines can keep a high work efficiency, and when wind
turbines exceed the synchronous speed, the electric produced by the rotor also can feedback to the
electricity grid by the converter [4]. The power of the rotor side converter of the doubly-fed unit is
about 1/3 of the total generating power of the generator set. The advantage is that the maximum
power can be captured in the larger wind speed, and the utilization rate of wind energy can be
improved, grid and output power are stable, flicker and electrical, mechanical impact small. The
disadvantage is that the converter's failure rate is higher than the constant speed wind turbine, and
the power output contains a certain harmonic component.

(4) Full power frequency conversion wind turbine

![](image)

Figure 4. Full power frequency conversion wind turbine.

Wind turbines connected to the grid through full-size power converter. You can use a
synchronous generator (SG) or an asynchronous generator (AG). The direct-drive wind turbine
model is a kind of new models which developed nearly 10 years, mainly USES the big polar
logarithmic low-speed permanent magnet or electric excitation synchronous generator directly
connected with the impeller, eliminating the high failure rate and difficult maintenance growth
gearbox, generator speed variable range is larger, alternating current (ac) from the synchronous
generator by the rectifier, booster, full power converter connected to grid. Full power frequency
conversion wind turbines without choppers inject post-fault power oscillations due to torsional oscillations. This is also the case for
Full power frequency conversion wind turbines with partially rated choppers. These oscillations are
normally not affecting the power system stability, but the effect of torsional oscillations may be
included using a two-mass mechanical model. If partially rated chopper is applied, then the
damping coefficient in the two-mass model can be adjusted to match the rating of the chopper.

(5) Squirrel cage motor plus full power converter

Only a handful of several wind power enterprises to adopt this technology, USES the squirrel
cage induction generator, the generator stator side join full power converter, realize a wide range
adjustment of generator speed, and the output current is at the same frequency as the grid. The
advantage is that the motor has high reliability, and the system has good low-voltage-ride-through
performance.

By comparison of wind turbine technology, in order to get wind energy more effectively,
doubly-fed variable speed wind turbine model has become the mainstream in the market now. As
more and more large-scale wind power systems are connected to the grid, it is also the most
important technology for large wind turbines to realize variable speed constant frequency.

Technical Method of Variable Speed Constant Frequency for Large Wind Turbine Generator

(1) Variable-speed constant-frequency technology

Variable-speed constant-frequency technology refers to the speed of the generator in the wind
power generation can vary with the wind speed, and the constant frequency can be obtained through
other control methods. By adjusting the size of the generator rotor current, frequency and phase, or variable pitch control, can adjust speed, can be in a very wide range of wind speed near constant optimal tip speed ratio, and then realize the pursuit of wind maximum conversion efficiency; At the same time, a certain control strategy can be used to flexibly adjust the active and reactive power of the system, so that it can greatly improve the stability of wind farm into the grid.

Compared with the previous constant speed constant frequency wind power generation technology, the variable speed constant frequency electric technology has many advantages[5,6], for instance: Variable speed constant frequency electric control system of the unit can control the field current or voltage amplitude, frequency, phase, and realize the output power of constant frequency and constant pressure, and to achieve the generator output decoupling control of active power and reactive power, improve the wind power generators and power system operation dynamic and static stability; With the variable speed constant frequency electric technology, the flexible connection between the generator set and the power grid system can be achieved[7,8].

(2) Variable speed constant frequency realization method

Variable speed constant frequency wind turbine realizes the goal of improving wind energy efficiency and ensuring power quality by the control of the electric part of the generator and the control of the blade pitch angle.

Of course, the control strategy is different for different types of generators. If the variable speed constant frequency wind turbine is used for synchronous generator, the control strategy of wind power unit is designed with the aim of capturing wind energy with maximum efficiency and ensuring stable operation of synchronous generator and inverter. It can also use the control of the active power of the generator to realize the tracking of the optimal tip speed ratio of the wind turbine; the voltage constant of the inverter side ac bus is realized by controlling the reactive power between inverter and the power grid; the stable operation of the dc converter is realized by adjusting the automatic voltage regulator in parallel to the generator side. Or through derivation, establish the active power characteristics and reactive power characteristics of the variable speed constant frequency doubly-fed wind turbines under the stator rotation coordinate system, and determine the control strategy of active power and reactive power of wind turbine in this coordinate system. In this way, the theoretical basis of the directional vector control of the stator field of the variable speed constant frequency doubly-fed wind turbine is determined. Another kind of variable speed constant frequency wind power generation system of active power and reactive power control strategy is under the stator field-oriented vector control, the active power and reactive power decoupled, and the minimum loss of the entire power system as the goal to control the reactive power.

Summary

In this paper, we first provide effective technical solutions for large-scale wind power generation by discussing the variable speed constant frequency technology of large wind turbines. In order to guarantee safety and stable operation of power grid, the variable speed constant frequency wind turbine wind power will become the mainstream, make full use of the power of relatively mature technology to control the generator system, realize the simultaneous and safe parallel operation in a certain power factor range. And in the power grid when needed, by increasing the reactive power support grid voltage recovery, fundamentally improve the parallel operation performance of wind turbines, enhance the ability of dealing with power grid failure, improve the stability of the wind turbines and electric power system operation. At the same time, it also provides some technical reference for the study of other large-scale wind turbines and the offshore wind turbines. It is hoped that the new grid wind turbines will no longer require large frequency conversion devices, reduce the occupancy space, effectively reduce the volume and quality of the cabin, and improve the utility of wind turbines. In addition, the wind turbines can also be combined with other relatively mature design and manufacturing technology base, the more powerful the reliability of wind turbines to a higher request.
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