

Comparative Analysis of Wind Energy Conversion System using DFIG and IG

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Abstract-Wind power is one of the fastest growing new generation technologies, and this pace of growth is likely to continue for several coming years. The future of wind energy for electric power is extremely bright and there is no doubt that in the renewable energy sector, wind power would play a predominant role in adding to the grid, clean and non-polluting energy to a substantial extent. In recent years, there is a strong trend towards generation of wind power across the globe in geographically suitable areas with a more or less stable wind velocity. However, the erratic nature of wind velocity as a power source is leading to problems of voltage/frequency oscillations and stability in wind energy conversion systems (WECS). In a lot of power systems renewable energies and especially wind power are main drivers for the actual restructuring of transmission and distribution systems. Enhanced power exchange capabilities over long distances will be one of the necessary transmission system characteristics in order to achieve a higher penetration level of wind power. Therefore, wind power must also participate in maintaining the quality of supply, power system security and stability. Voltage control and the management of active and reactive power flows are typical tasks to be resolved. In this paper the doubly fed induction generator (DFIG) is proposed to ensure the continuous quality power. The performance of WECS using DFIG and induction generator is analysed.

Keywords- Wind power, Wind energy conversion system (WECS), renewable energy.

I. INTRODUCTION

Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the wind.

Wind is the motion of air masses produced by the irregular heating of the earth's surface by sun. These differences consequently create forces that push air masses around for balancing the global temperature or, on a much smaller scale,

the temperature between land and sea or between mountains [1-4].

Wind energy is not a constant source of energy. It varies continuously and gives energy in sudden bursts. About 50% of the entire energy is given out in just 15% of the operating time. Wind strengths vary and thus cannot guarantee continuous power. It is best used in the context of a system that has significant reserve capacity such as hydro, or reserve load, such as a desalination plant, to mitigate the economic effects of resource variability.

Because instantaneous electrical generation and consumption must remain in balance to maintain grid stability, this variability can present substantial challenges to incorporating large amounts of wind power into a grid system. Thus, intermittency of wind seldom creates problems when using wind power to supply a low proportion of total demand [5-8].

The siting of wind turbines can be problematic, due to opposition to their appearance, noise and potential hazard to wildlife.

Transmission is another significant hurdle, since the best sites for wind energy development often are far away from urban centers and the wire networks that provide them with power.

Other critics say that wind energy, like other forms of alternative energy, is not really economically viable without substantial government subsidies and incentives. Still, if adopted as complementary source, it can reduce the high cost of utilities. In this paper the WECS model using DFIG and induction generator are simulated. The mathematical model of WECS is presented and their performance is analysed.

II. FUNCTIONAL STRUCTURE OF WIND ENERGY CONVERTER

A schematic diagram of a wind energy conversion system is presented along with a detailed description of wind turbine and its modelling. The functionality of other system components is also discussed briefly.

The functional structure of a typical wind energy conversion System is as shown in Figure 1:

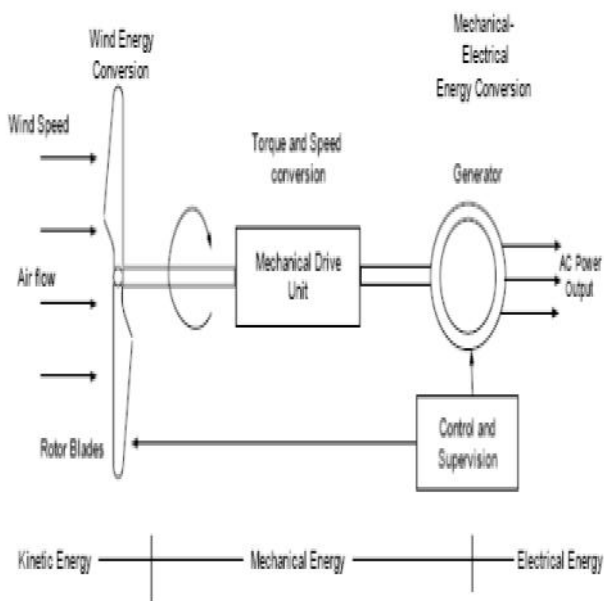


Fig. 1. Power Transfer in a Wind Energy Converter

A wind energy conversion system is a complex system in which knowledge from a wide array of fields comprising of aerodynamics, mechanical, civil and electrical engineering come together. The principle components of a modern wind turbine are the tower, the rotor and the nacelle, which accommodates the transmission mechanisms and the generator. The wind turbine captures the wind's kinetic energy in the rotor consisting of two or more blades mechanically coupled to an electrical generator. The main component of the mechanical assembly is the gearbox, which transforms the slower rotational speeds of the wind turbine to higher rotational speeds on the electrical generator side. The rotation of the electrical generator's shaft driven by the wind turbine generates electricity, whose output is maintained as per specifications, by employing suitable control and supervising techniques. Besides monitoring the output, these control systems also include protection systems to protect the overall system [9]. Keeping in view of above mentioned important point the DFIG is selected to ensure the quality power generation with better and reliable control for the wider range of wind velocity. In the coming sections of this paper the DFIG based WECS is analysed.

III. MODEL OF WIND TURBINES

Wind turbines model based on different generator technologies such as simple induction generator or doubly fed induction generator with identical rated power (1.5MW) are presented. As in Figure 1, a simple configuration of different types of wind turbines concept is shown.

A. Doubly Fed Induction Generator Model

The DFIG is a wound-rotor induction generator whose stator is directly connected to the grid, but the three phase rotor windings are connected through slip rings to the grid via a

partially rated power electronics converter. A typical configuration of a DFIG is shown.

The DFIG can be regarded as a traditional induction generator with a nonzero rotor voltage. For representation of DFIG models in power system stability studies, the stator flux transients are neglected in the voltage relations [10].

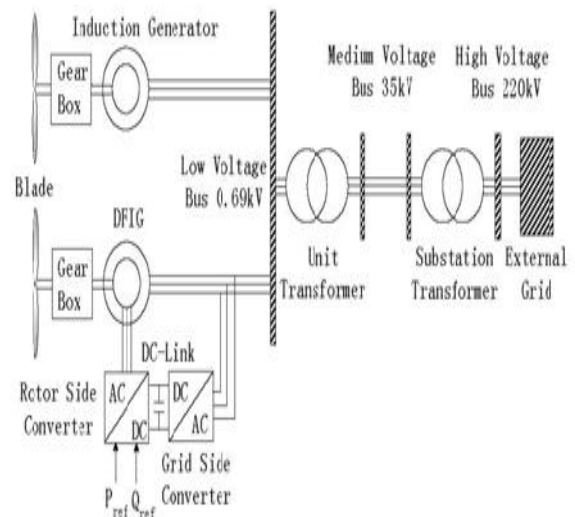


Fig.2 Configuration of IG based wind turbines and DFIG based wind turbines and interconnection of grid.

The power converter in such wind turbines only deals with slip power, therefore the converter rating can be kept fairly low, approximately 20% of the total generator power [11]. The PWM converter inserted in the rotor circuit allows for a flexible and fast control of the generator by modifying magnitude and phase angle of the rotor voltage. The controllability of reactive power help DFIG equipped wind turbines play a similar role to that of synchronous generators. Under steady-state conditions, the flux transient's items disappear.

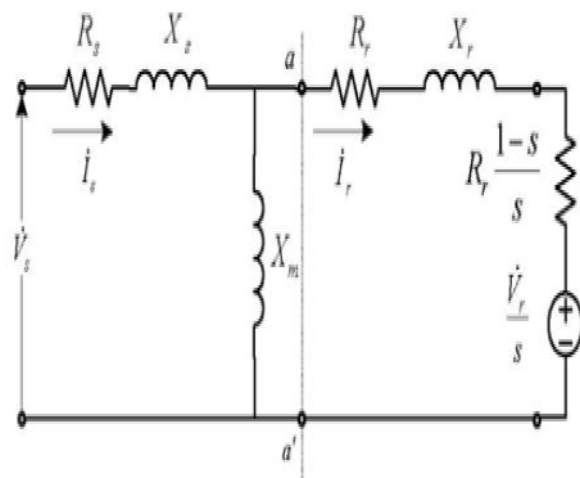


Fig. 3 Steady-state equivalent circuit of doubly fed induction generator

During normal steady-state operation the wind turbines or the wind farm can be considered as a PQ node or a PV node depending on the control strategy that the wind farm adopted.

B. Induction Generator Model

The rotor of induction generator is a wound-rotor or a squirrel-cage rotor with a short circuit winding not connecting to an external voltage source. The steady-state equivalent circuit of the induction generator is given in Figure 3.

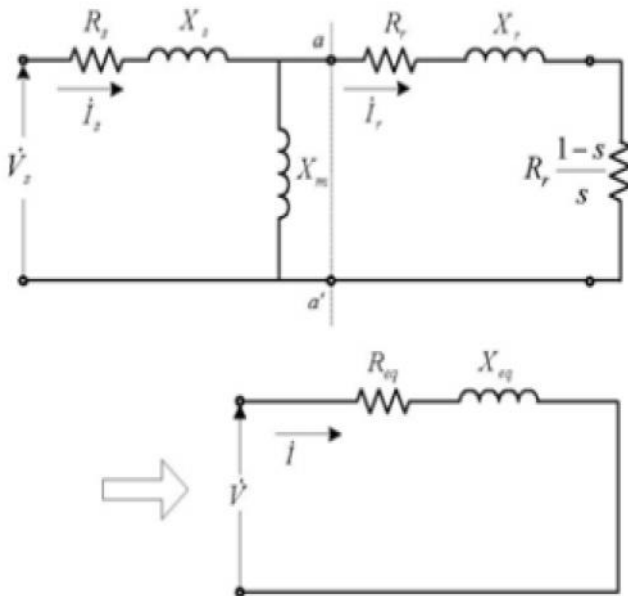


Fig. 4 Steady-state equivalent circuit of induction generator

IV. CONTROL STRATEGY OF DFIG BASED WIND TURBINES

DFIG make use of power electronic converters and are thus able to regulate their own reactive power, so as to operate at a given power factor, or to control grid voltage. The rotor-side converter is controlled by a two stage controller. The first stage consists of fast current controllers regulating the generator rotor currents to reference values that are specified by a slower power-controller which is the second stage controller. There are two independent PI controllers, one for the d-axis component, and one for the q-axis component. The output of the current controller defines the pulse-width modulation factor P_m in stator voltage orientation. Voltage control can also be realized by replacing the reactive power controller by a voltage controller defining the d-axis current reference. Up to now, this feature of the DFIG based wind turbine is mainly used to keep the generator reactive power neutral. However, as wind power penetration in power systems is increasing, it will probably be desirable for wind turbines to provide voltage control. The controller can regulate either the voltage or the power factor, but the maximum possible reactive power production is defined by the converter ratings.

V. STEADY-STATE VOLTAGE STABILITY ANALYSIS

In this section, the steady-state voltage stability limit of wind farms based on different wind turbine technologies is assessed. Three cases are conducted:

case (1) wind turbines equipped with no-load compensated induction generator; case (2) wind turbines equipped with full-load compensated induction generator; case (3) wind turbines equipped with DFIG controlling the POI as a PQ node with $Q = 0$ MVar.

A. P-V Curve Analysis Of Wind-Farm With Different Generator

Wind farms based on different types of wind turbines are interconnected into the transmission grid. When the active power output of wind farm is low, the POI voltage does not affected significantly but when wind power injects into the POI increasing largely then the voltage decreases fast. The P-V curves of the wind farms as wind farm active power output increasing are plotted in Figure 8.

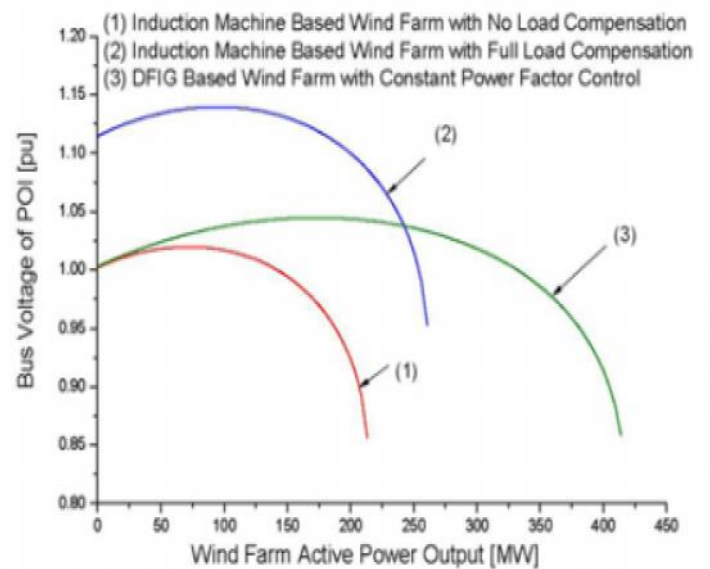


Fig. 5 P-V curves of wind farms based on different wind turbine technology

It can be that the steady-state voltage stability limits of induction generator based wind farm with no-load compensation is only 213MW. When more real wind power injects into the POI than 213MW, the voltage will collapse. When the DFIG based wind farm with constant power factor control that control the POI as a PQ bus with $Q = 0$ MW, the steady-state voltage stability limits are increased largely to 424MW. When 350MW real wind power injects into the grid, the voltage stability margin can be acceptable. It must be noted that induction generator based wind farm with full-load compensation can enhance the voltage stability limit, but not very obviously; the full-load shunt capacitor compensation should not be put into use in low wind power output totally or else that will arise bus voltage higher than acceptable voltage level such as the curve (2). In actual operation of wind farm with full-load compensation, the shunt capacitor should be switched on gradually along with the active power output increasing. Due to the shunt capacitors compensation, the voltage collapse value in case (2) equal to 0.95 pu is higher

than that in case (1) or case (3) equal to 0.85 pu. Because the reactive power output of shunt capacitors is proportional to V^2 as the grid voltage decreasing, the capacitors cannot provide the rating reactive power. The shunt capacitor's reactive power capability is limited in case of lower voltage and cannot improve the voltage stability of the local grid fundamentally.

B. V-Q Curve Analysis Of Wind-Farm With Different Generator

V-Q curve is a powerful tool to analysis the steady-state voltage stability limits and reactive power margins of the grid by describing the relationship between the bus voltage and the injected reactive power into the same node. It illustrates the reactive power distance from the normal operation point to the voltage collapse point. In the case of induction generator based wind farm with no-load compensation, there is a 13MVar reactive power margin when the wind farm active power output is 200MW; in the case of DFIG based wind farm, there is a 12MVar reactive power margin when the wind farm active power output is 400MW. The acceptable injected real wind power in case (3) double than that in case (1) because the DFIG based wind turbines can provide the reactive power to keep a constant power factor of the whole wind farm and reactive power exchange zero in the POI. This characteristic of DFIG based wind farms would enhance the voltage stability of the local grid integrating wind power. High demand of reactive power is the major characteristic of large wind farms that causes voltage problems to power networks. The larger the wind farm, the more severe this effect could be. If the network is not able to meet the wind farm reactive power requirement, the wind power penetration into the power system should be limited.

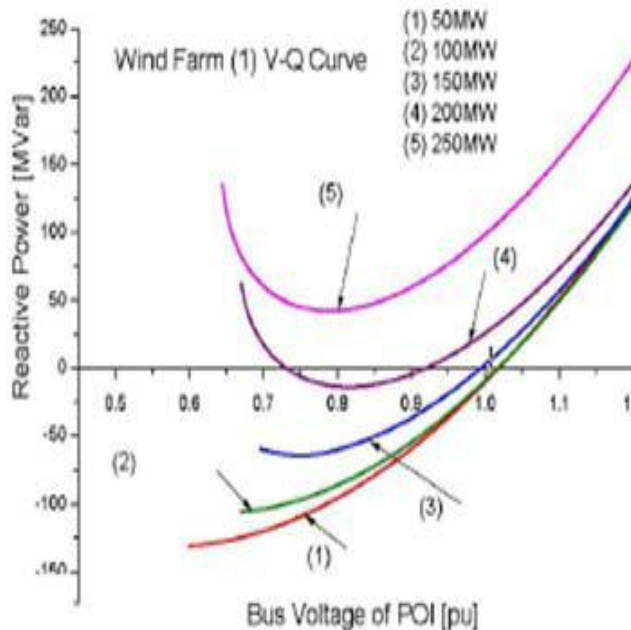


Fig. 6 V-Q curve of wind farm based on IG with no-load compensation

In all the study cases, the DFIG based wind turbines have a better voltage recovery performance than the same rating IG based wind turbines. Due to the control capability to regulate reactive power and voltage, the DFIG wind turbines will mitigate the adverse affect on voltage stability of the local transmission grid.

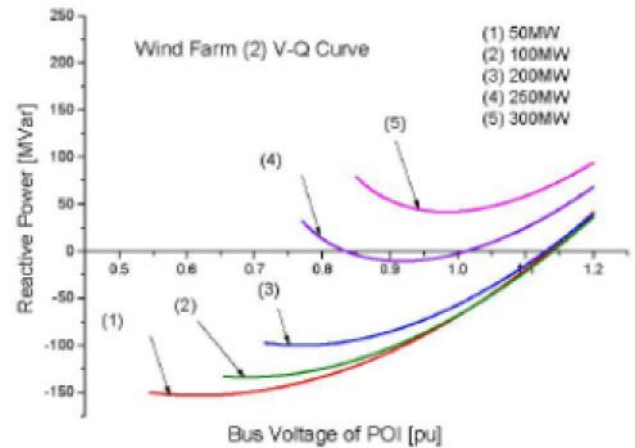


Fig. 7 V-Q curve of wind farm based on IG with full-load compensation

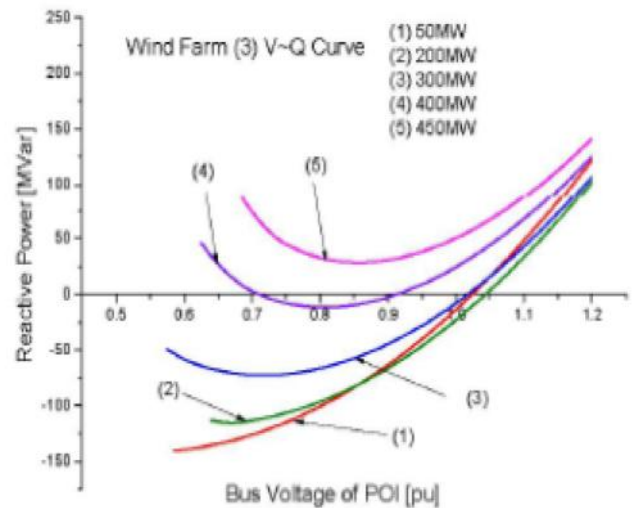


Fig. 8 V-Q curve of DFIG based wind farm

VI. CONCLUSIONS

In this paper it is conclude that wind has a lot of potential in it and if properly harnessed then it can help to solve the energy crises in the world. The study of wind turbine and its characteristics showed that how it can be properly

designed and used to get the maximum output. The application of power electronic control played an important role to ensure maximum possible power generation for wider range of wind velocity. The application of DFIG with power electronic converter ensures the quality power generation. With the application of power converters with DFIG, not only the operations have been smoothed but also the efficiency has been increased to a great extent. From the voltage stability analysis it is observed that the doubly fed induction generator has superior characteristics than a simple induction generator.

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