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The Impact of Wind Power Implantation in Transmission Systems

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Abstract

The use of renewable energy sources in world will increase, leading to a more sustainable energy mix, reduced greenhouse gas emissions and a lower dependency from oil. Wind power is one of the renewable energy sources that have virtually no environmental problems; it is one of the fastest growing sources of energy in the world. In industry, the wind power creates new jobs, encourages innovation. Most research on wind power has been concerned with producing electricity. This effort restarted in the United States in the early 1970s. However, the largest disadvantage of wind energy is the lack of exact predictability and its fluctuations, which are causing problems in the power flow of transmission system when the weak nature of the grid in remote areas and the uncertainty of wind are taken into consideration.

Keywords: wind power, renewable energy, novel electrical production

1. Introduction

Today, renewable energy power systems can be a cost effective alternative for areas with high electricity connection fees. It is also possible to connect wind power systems to the grid, reducing the amount of electricity you need to purchase, or in some cases, allowing you to export surplus power into the grid. Wind is the most promising sources and its penetration level to the grid is also on the rise. Although the benefits of distributed generation includes voltage support, diversification of power sources,

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reduction in transmission and distribution losses and improved reliability, power quality problems are also of growing concern. [1]

The wind energy is considered to be a viable contribution to the energy industry. In addition to the environmental benefits, the wind power penetration increases the utility's reserve capacity by adding converted wind power into electricity. The wind can provide power to remote areas therefore, relieving the generating and distribution utilities from expanding their resources. They can also be integrated with existing transmission or distribution networks [2]. When the wind turbine is connected to the distribution network –grid integrated- ancillary services are likely to be supplied by the hosting utility, which can impose stress, cost and increase the network vulnerability to instabilities.

There is no doubt that wind power will play a predominant role in adding clean and nonpolluting energy to the country's grid. However, as more wind turbines are connected to the grid, their impact on the power quality of services populated with wind generation is becoming more evident, so it is important to analyze the transient stability of power system including wind power stations [4].

The wind speed fluctuates on several time scales due to movement of air masses and numerous meteorological phenomena. These variations influence wind power both in terms of consistency of generated power which causes power quality concerns when wind power is integrated into the energy systems. The consequent intermittency of wind power may cause imbalance between local power demand and power generation which in turn may lead to adverse voltage variations and other effects. The penetration of wind power has reached levels high enough to affect the quality and stability of the grid.

Large number of wind energy conversion systems forms wind farms 'wind power plants' are made of either inland or offshore wind turbine generating units (figure 1).

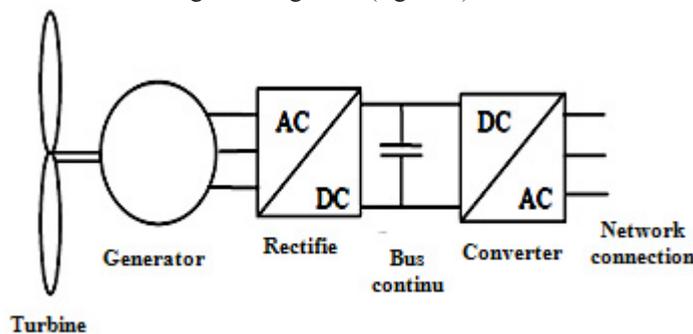


Fig.1. Wind energy conversion systems

Global installed wind generation capacity has increased from 2,500 megawatts (MW) in 1992 to more than 59,000 MW by June 2006, at an annual growth rate of near 30%. Almost three quarters of this capacity has been installed in Europe. European Wind Energy Association (EWEA) scenarios show that the future prospects of the global wind industry are promising and the total wind power installed worldwide could quadruple to 160,000 MW by 2012 [2].

2. Wind turbines grid connection

Wind power integration presents important issues in terms of operational and extension modifications of power systems structure, connection requirements for wind turbines in order to maintain a stable and reliable supply, and its influence on the security of supply. Moreover, as wind power has grown faster than expected, and its penetration rates and codes are steadily being reformulated.

2.1. Transmission network

Wind power integration at transmission level must be focused in the global system control and at stability problems. Transmission network operators have to take care of the power balance between generation and demand, that is, security of supply.

2.2. Distribution network

Wind power integration at distribution level focus on more local power quality problems. Distribution network operators take care of keeping the power quality, which means that the voltage seen by consumers is within acceptable limits.

3. Wind Turbine Induction Generator Models

Induction generators (IG's) consume reactive power to establish the magnetic field in which its quantity depends on the magnetizing element, operating speed as well as supplied load [2]. This is evident by examining an induction generator characteristic as the operating slip is varied by 10% above the synchronous speed as shown in Figure 2.

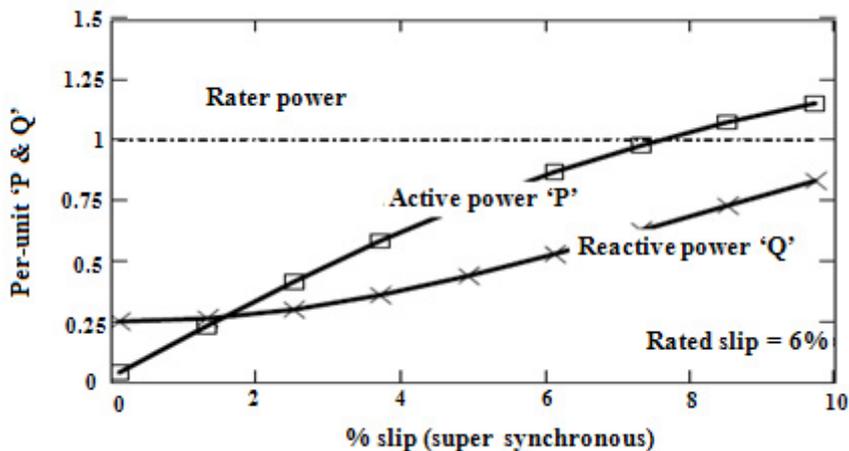


Fig.2. Induction Generator Active 'P' and Reactive 'Q' Power Relation versus the % Slip above the Synchronous Speed.

Integration with the utility grid takes many configurations that depend on the used electronic conversion system.

There are many different types of wind turbines in use around the world, each having its own list of benefits and drawbacks [4, 5]. There are two types of IG's used the wind industry depending on how the rotor is manufactured and its conductors are connected:

The squirrel cage induction generator (SCIG) which consists of a grid coupled short-circuited induction generator. The wind turbine rotor is connected to the generator through a gearbox. The SCIG that uses one set of poles and provides a wider slip range control is shown in Figure 3. The increase in the speed range is achieved by using power converter that regulate the flow of power and maintain the voltage and frequency within the grid limits. The power extracted from the wind is limited in high wind speeds using the stall effect. No active control systems are used [4]. This scheme can provide some support of the

reactive power as it has a capacitor in the dc link of the AC-DC-AC converter. But still, it will rely on the grid to support the varying reactive power that cannot be met by the converter [2].

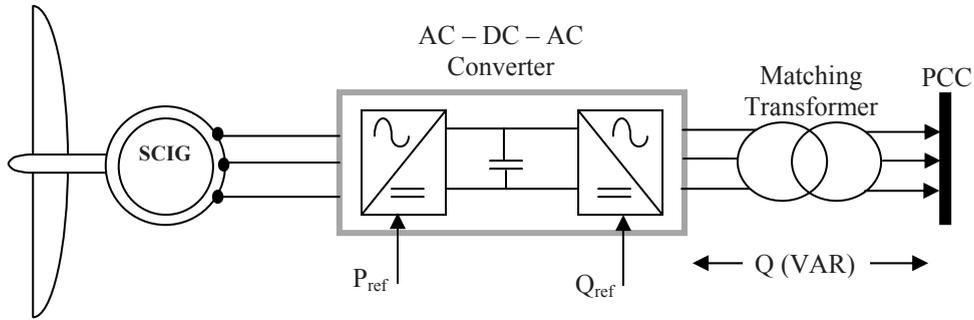


Fig.3. SCIG grid connected Wind Energy Conversion Systems -, P and Q control

Wound rotor induction generator (WRIG) where the rotor conductors are connected to slip rings allowing access to the rotor circuitry with doubly-fed induction generator (DFIG) when the rotor winding is supplied using a back-to-back voltage source converter [4, 11]. WRIG allows power to flow from the stator as well as the rotor to recovery some of the otherwise dissipated slip power. A more accurate control at a wider range is the slip energy recovery scheme shown in Figure 4. Here WRIG feeds power from the stationary side and from the rotor when driven above the synchronous speed [2].

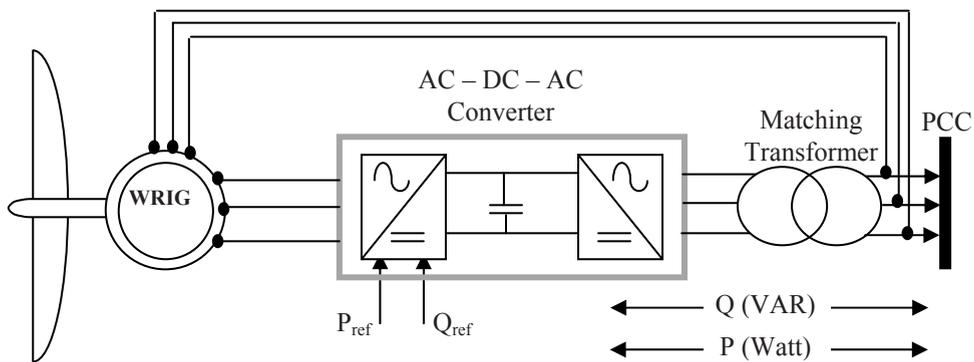


Fig.4. WRIG grid connected Wind Energy Conversion Systems - 'double fed', P and Q control

It is evident from the various schemes that the IG must have adequate reactive power source capable of running the system at various wind velocity. Many hosting utilities require that WECS operator to provide a proper means to compensate for the reactive power continuously drawn from the grid and maintain a healthy power factor at the point of power injection.

4. Wind Energy Conversion System

The power extraction of wind turbine is a function of three main factors: the wind power available, the power curve of the machine and the ability of the machine to respond to wind fluctuation [6]. The function of the wind power module is transformed into mechanical energy by means of a wind turbine

whose rotation is transmitted to the generator by means of a mechanical drive train [5, 7].

The wind-power equation is given by:

$$P_t = \frac{1}{2} \rho \pi r^2 v^3 C_p(\lambda, \theta) \tag{1}$$

Where P_t is the mechanical power extracted from the wind, ρ is the air density in kg/m³, r is the turbine radius in m, v is the wind speed in m/sec, and C_p is the turbine power coefficient which represents the power conversion efficiency and is a function of λ and θ . λ is the ratio of the rotor blade tip speed and the wind speed (v_{tip}/v), θ is the blade pitch angle in degrees. C_p is a characteristic of the wind turbine and is usually provided as a set of curves (C_p curves) relating C_p to λ , with θ as a parameter.

The tip speed ratio is defined as:

$$\lambda = \frac{R \omega}{\mu} \tag{2}$$

Where ω is the rotor speed. It is seen that if the rotor speed is kept constant, then any change in the wind speed will change the tip-speed ratio, leading to the change of power coefficient C_p as well as the generated power out of the wind turbine. If, however, the rotor speed is adjusted according to the wind speed variation, then the tip-speed ratio can be maintained at an optimal point, which could yield maximum power output from the system.

From Eqs. (1) and (2) we can see that:

$$P_m(\omega) = k_w \omega^3 \tag{3}$$

Where:

$$k_w = \frac{1}{2} C_p \rho \pi \frac{R^5}{\lambda^3} \tag{4}$$

Figure 5 above shows wind turbine characteristic used for this study with the turbine input power plotted against the rotor speed of the turbine. The turbine mechanical power as function of turbine speed is displayed for wind speeds ranging from 4 m/s to 10 m/s.

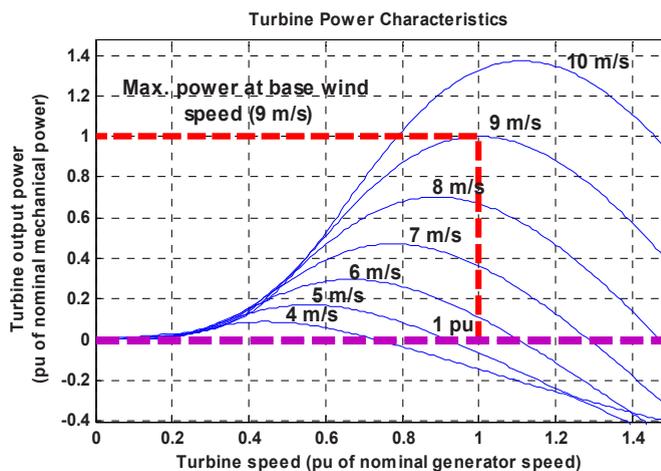


Fig.5. Turbine characteristic with maximum power point tracking for IG

The advantage of using synchronous generator is whenever the wind speed is very low power can be supplied from the synchronous generator which can be driven by the Diesel engine. When wind speed is high synchronous generator can be used to excite the induction generator with zero power input.

Such disturbances are the most common in the grid, the grid disturbances considered in this paper are of short duration, maximum a few hundreds of milliseconds. Since the considered grid disturbances are much faster than wind speed variations, the wind speed can be assumed constant. Therefore, natural wind variations need not be taken into account. The wind speed is set to a constant 8 m/s [1].

5. Computation Results

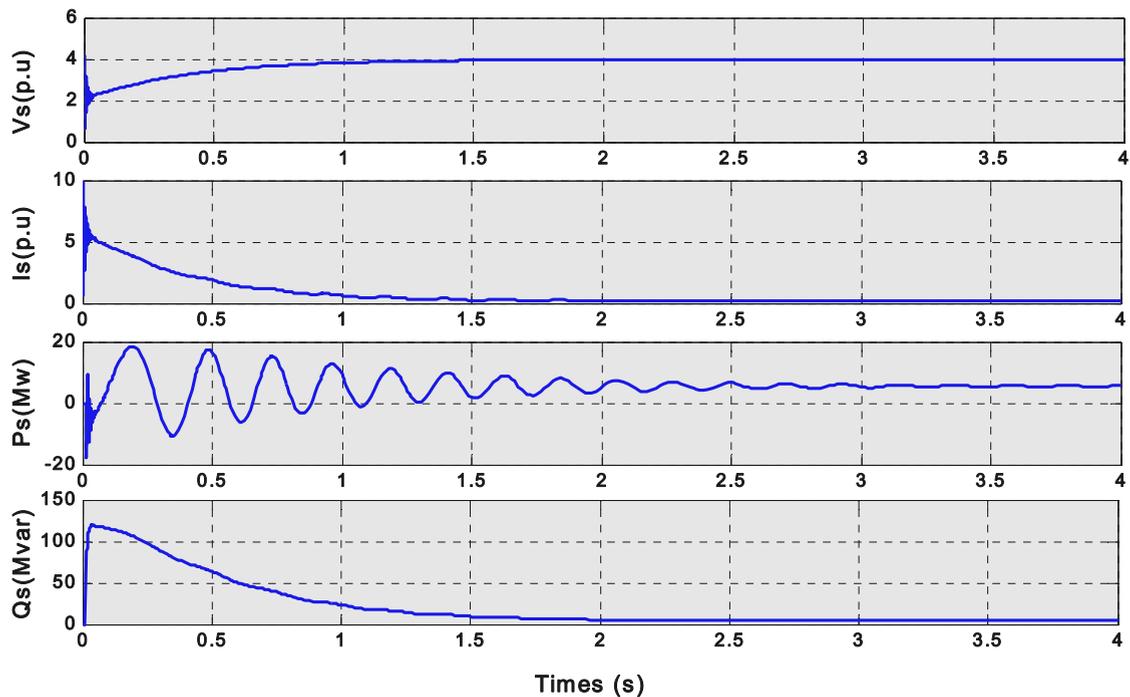


Fig.6. waveform of voltage, current, power active and power reactive in power supply connection

The proposed controller design was tested in simulation using MATLAB/SIMULINK. The generator model is an Induction generator when we integrated a six (06) of 1.5Mw in transmission network of 120Kv.

In Figure 6, the system is running under nominal conditions without the supplemental disturbance rejection control loops. The grid becomes unbalanced with a voltage of supply is stabilized at $t = 1.2s$, and power active presented the oscillations and stabilized at 3.6s. These oscillations are, consequently,

propagated to the power reactive and currents, when they are sagged at $t = 0.2$ s.

As a figure 6, the figure 7 presented the following waveforms of wind turbine characteristics, the speed of wind is fixed at 8m/s, the pitch angle is varied between $t = 0.125$ s and 1.76s. This figure shows significantly reduce the torque and reactive power pulsations, while also decreasing the sags of the stator current. Also, several steady state simulations were run, with the generator at synchronous speed and rated power.

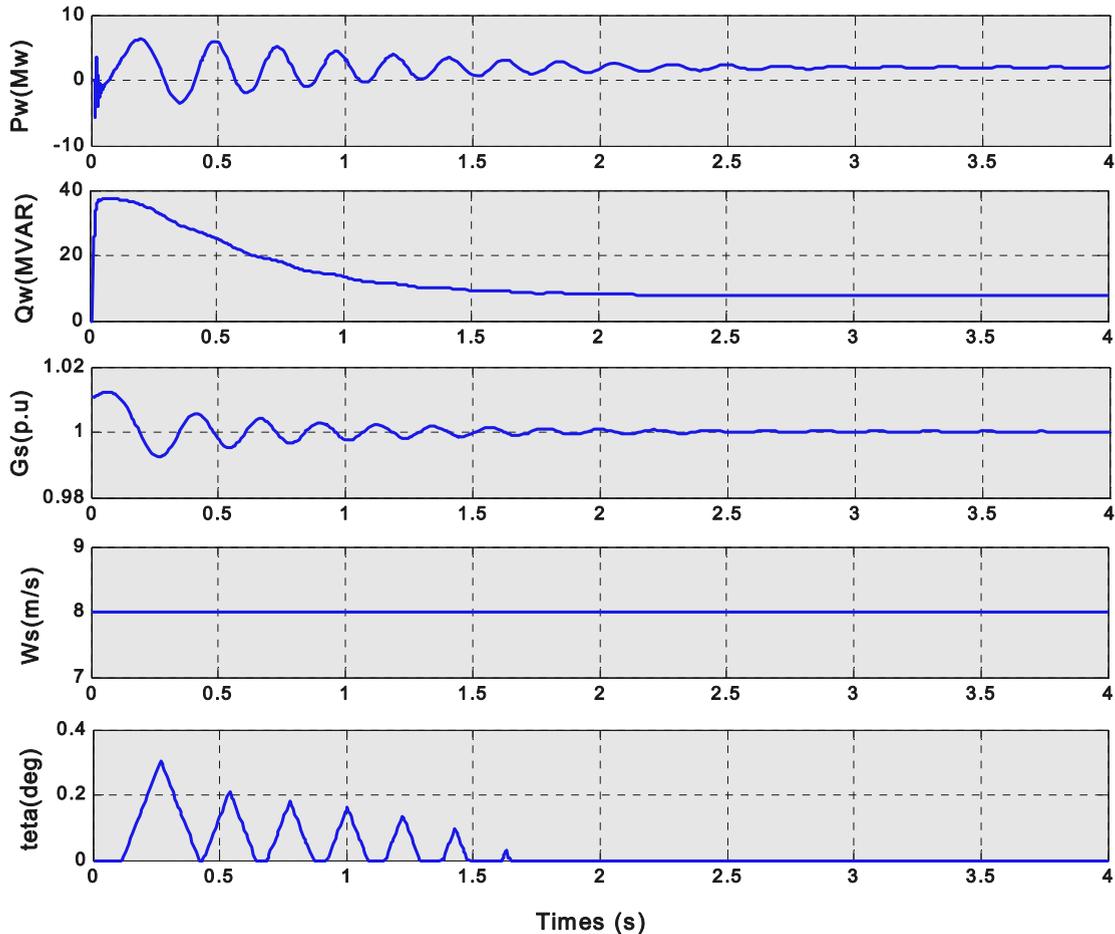


Fig.7. waveform of power active, reactive, speed and pitch of turbine and wind speed fixed in 8m/s.

6. Conclusion

The significant expansion of wind energy requires solving a series of technical economic questions. A current energy source, wind energy is the most advanced technology due to its installed power and the recent improvements of the power electronics and control. In addition, the applicable regulations favor the increasing number of wind farms due to the attractive economical reliability.

The new power-electronic technology plays a very important role in the integration of renewable energy sources into the grid. Recent developments in wind generation technology have solved several of

the serious problems posed by large wind farms connected to weak ac transmission grids.

The various technologies used for compensating the reactive power requirements to the individual generator and to a cluster of generators forming a wind farm. Installing FACTS such as SVC or STATCOM is important to maintain controllable reactive power flow between the generating units and the utility network. Dynamic compensation of reactive power is an effective means of safeguarding power quality as well as voltage stability.

The power reactive compensators is connected at the PCC to compensate for the connecting lines losses as well as regulating the fluctuated reactive energy demand and mitigate voltage flicker. In this case, the study Application of STATCOM emerging in wind farm used the IG's to compensate the power reactive is presented in [1] when the power fluctuations are eliminates and this confirms the excellent performance of the proposed system for power quality improvement.

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