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SCIG Wind Energy Power Transmission and Conversion System

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Abstract: ***Wind energy is one of the fastest-growing electrical energy sources in the world. Wind energy resources, unlike dispatch able central station generation, produce power dependable on external irregular source and that is the incident wind speed which does not always blow when electricity is needed. This results in the variability, unpredictability, and uncertainty of wind resources. Therefore, the integration of wind facilities to utility electrical grid presents a major challenge to power system operator. Such integration has significant impact on the optimum power flow, transmission congestion, power quality issues, system stability, load dispatch, and economic analysis. grid operation is not only impacted by the uncertainty of the future production of wind farms, but also by the variability of their current production and how the active and reactive power exchange with the grid is controlled. To address this particular task, a control technique for wind turbines, driven by doubly-fed induction generators (DFIGs), is developed to regulate the terminal voltage by equally sharing the generated/absorbed reactive power between the rotor-side and the grid side converters. To highlight the impact of the new developed technique in reducing the power loss in the generator set, an economic analysis is carried out. Moreover, a new aggregated model for wind farms is proposed that accounts for the irregularity of the incident wind distribution throughout the farm layout The evolution of wind technology is expected to continue over the next two decades resulting in a continued improvement in reliability and energy capture with a modest decrease in cost. The development of new and innovative rotors, drive systems, towers, and controls are expected to enable this continued improvement in the cost effectiveness of wind technology. Wind energy can supply 20% of the United States' electricity needs by 2030 and will be a significant contributor to the world's electricity supply. The main focus behind this paper is to solve weakness of power demand in remote areas and reduce greenhouse gas effect with lower dependency from oil using integration of wind energy it also explores some of the design rationale behind such a power transmission system and uses exergy analysis to explain and evaluate its operation.***

Keywords: Wind energy, Transmission system wind turbine, SCIG, Power Energy

1.Introduction

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impacts. Wind energy conversion systems are the fastest growing renewable source of electrical energy having tremendous environmental, social, and economic benefits. Wind is the most promising sources and its penetration level to the grid is also on the rise. Although the benefits of distributed generation include voltage support, diversification of power sources. Reduction in transmission and distribution losses and improved reliability, power quality problems are also of growing concern. During the last decade wind turbines has been developed in size from 20kw to 2MW, while even larger wind turbines already are being designed. 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. In a wind farm, individual turbines are interconnected with a medium voltage (usually 34.5 kV) power collection system and communications network. At a substation, this medium-voltage electrical current is increased in voltage with a transformer for connection to the high voltage electric power transmission system. A transmission line is required to bring the generated power to (often remote) markets. For an off-shore plant this may require a submarine cable. Construction of a new high-voltage line may be too costly for the wind resource alone, but wind sites may take advantage of lines installed for conventionally fueled generation (Butterfield et al.2006). One of the biggest current challenges to wind power grid integration is the necessity of developing new transmission lines to carry power from wind farms, usually in remote lowly populated states in the middle of the country due to availability of wind, to high load locations, usually on the coasts where population density is higher. The current transmission lines in remote locations were not designed for the transport of large amounts of energy as transmission lines become longer the losses associated with power transmission increase, as modes of losses at lower lengths are exacerbated and new modes of losses are no longer negligible as the length is increased, making it harder transport large loads over large distances. However, resistance from state and local governments makes it difficult to construct new transmission lines. Multi state power transmission projects are discouraged by states with cheap electricity rates for fear that exporting their cheap power will lead to increased rates. A 2005 energy law gave the Energy Department authority to approve transmission projects states refused to act on, but after an attempt to use this authority, the Senate declared the department was being overly aggressive in doing so. Another problem is that wind companies find out after the fact that the transmission capacity of a new farm is below the generation capacity, largely because federal utility rules to encourage renewable energy installation allow feeder lines to meet only minimum standards. These are important issues that need to be solved, as when the transmission capacity does not meet the generation capacity, wind farms are forced to produce below their full potential or stop running all together, in a process known as curtailment. While this leads to potential renewable generation left untapped, it prevents possible grid overload or risk to reliable service. 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 This new revolution in electricity generation from wind energy has caught the attention of researchers and their interests are quite clear in numerous publications regarding wind turbines and wind farms. The rapid growth in the capacity of wind turbines and the number of the installed wind farms requires more intensive research in many fields. Researchers need to focus on the prediction of wind farms' output power, advanced reactive power control techniques for large wind farms, and developing more accurate models to simulate the dynamic performance of wind farms under various operating conditions. From figure 1.0 it is clear that production of electricity from wind is increasing year by year. Moreover, the future plan for wind farms to operate as power plants and to become active controllable power elements in power systems capable of replacing non-renewable energy resources power plants, necessitate more accurate methods for wind speed and energy prediction, as well as more accurate, reliable, and economical control techniques.

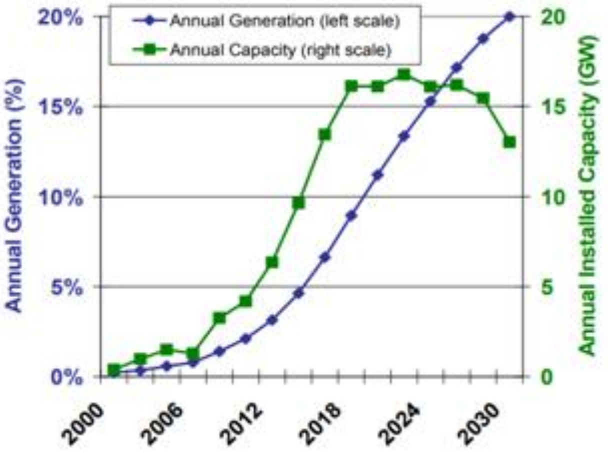

Figure 1.0: World wind energy production capacity

The scenario does assume a modest improvement of wind technology over the 20-year modeling period. Wind turbine costs are assumed to decrease by 10% to 12% between 2010 and 2020, and wind turbine performance, or capacity factor, is assumed to increase to 50%, up from today's capacity factors of 35%, by the year 2030. Although these increases do not appear to be particularly aggressive, they are quite challenging and represent a significant technical challenge given the present situation where turbine costs are increasing with time.

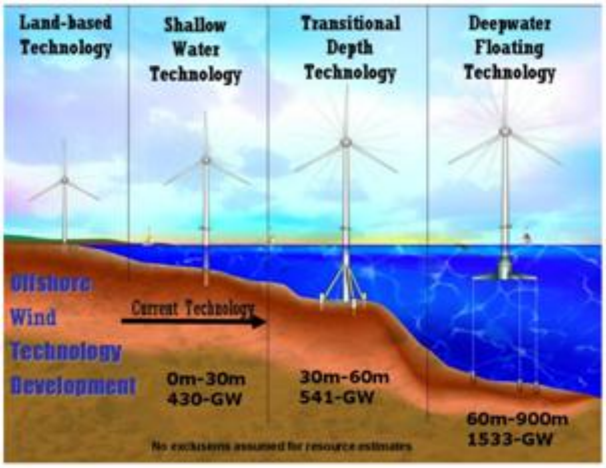

Figure 2.0: Offshore development pathways.

Offshore technologies will be required to grow wind turbines into 5 to 10 MW sizes or greater. These technologies may include lightweight composite materials and composite manufacturing, lightweight drive train, modular pole direct drive generators, hybrid space frame towers, and large gearbox and bearing designs that are tolerant of slower speeds and large scale. The cost of control systems and sensors that monitor and diagnose turbine status and health will not grow substantially as turbine size increases, and high reliability will be essential due to the limited access during severe storm conditions, which can persist for extended periods. It is expected that over the next five years, one or more offshore wind farms will be deployed in the United States. They will be installed in shallow water and supply electricity to nearby onshore utilities serving large population centers. If they are successful, the technology will develop more rapidly and the move to deep water systems will progress at a more rapid rate. However, the path toward floating systems must be supported by an extensive R&D program over a decade or more.

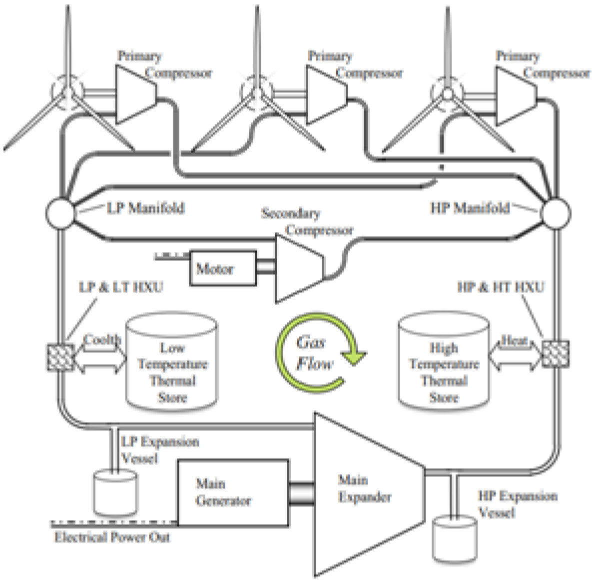

Figure 3.0: Flow Diagram of wind energy power transmission

2.Induction Generator Model

There are many different types of wind turbines are used around the world. There are two types of IG have used the wind industry depending on how the rotor is manufactured and its conductors are connected. Induction generators, often used for wind power projects, require reactive power for excitation so substations used in wind-power collection systems include substantial capacitor banks for power factor correction. Different types of wind turbine generators behave differently during transmission grid disturbances, so extensive modeling of the dynamic electromechanical characteristics of a new wind farm is required by transmission system operators to ensure predictable stable behaviour during system faults (see: Low voltage ride through). In particular, induction generators cannot support the system voltage during faults, unlike steam or hydro turbine-driven synchronous generators. Doubly fed machines—wind turbines with solid-state converters between the turbine generator and the collector system—generally have more desirable properties for grid interconnection. Transmission systems operators will supply a wind farm developer with a grid code to specify the requirements for interconnection to the transmission grid. This will include power factor, constancy of frequency and dynamic behaviour of the wind farm turbines during a system fault. This is evident by examining an induction generator characteristic as the operating slip is varied by 10% above the synchronous speed. The squirrel cage induction generator (SCIG) which consists of a grid coupled short-circuited induction Schematic of the power transmission system of interest 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. 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. 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.

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. 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. Here WRIG feeds power from the stationary side and from the rotor when driven above the synchronous speed. 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.

3.Wind Energy Conversion System

Wind energy conversion system is set of elements that is responsible to convert the wind energy in to appropriate form of energy. 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. 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.

The wind-power equation is given by:

$$Pt\ =\ ½\ \rho\ \pi r\ 2c\ 3\ Tp\ (\lambda,\theta)$$

Pt= mechanical transmission power extracted from the wind,
ρ=air density in kg/m3,
r = Turbine radius in m2,
c= Wind speed in m/sec
Tp =Turbine power coefficient which represents the power conversion efficiency and is a function of λ and θ.
λ= Ratio of the rotor blade tip speed and the wind speed (v tip /v), θ=Blade pitch angle in degrees.

$\lambda = kw/c$

Where $C = Wind\ speed\ in\ m/sec$
$k = Rotor\ speed$

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 Cp 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.

Figure 4.0 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 5 m/s to 9 m/s.

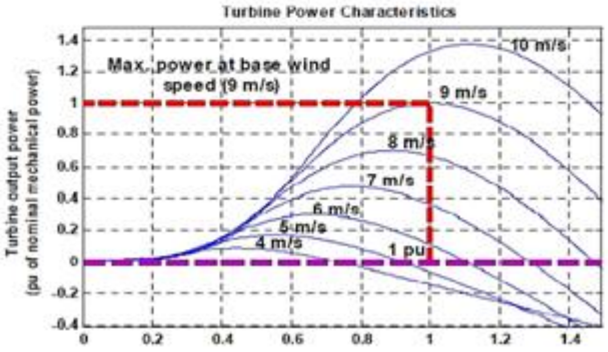

Figure 4.0: Turbine characteristic for IG

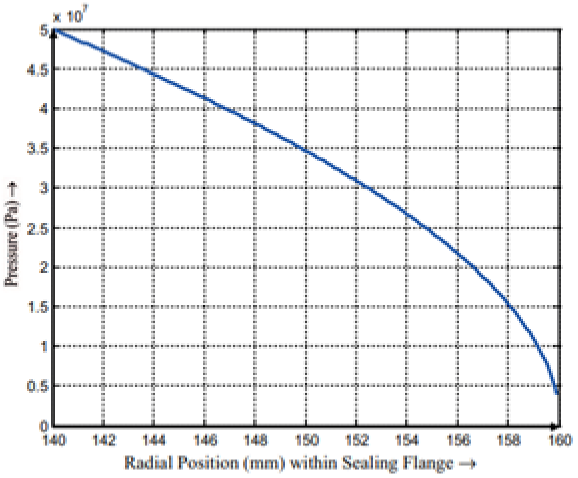

Figure 5.0: Pressure drop (Pa) vs. radius (mm) through a plain annular gap

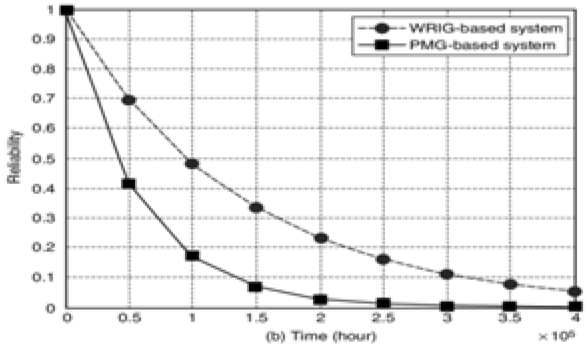

Figure 6.0: Reliability of the power conditioning system a) Over a year, b) Over time.

It is important to note that remaining in mode A does not require that the wind should remain at or above rated wind speed. Any one of operating modes A-C can be operated at part load to suit conditions and there is no restriction on changing the load level in any one operating mode arbitrarily quickly. It is also important to note that the main effect of the thermal inertia is a delay in the actual implementation of a mode-change rather than a large loss of exergy - though clearly some exergy is lost in each mode change through irreversibility in the heat transfer. Work into the loss of exergy per instance of mode change is ongoing. The power-transmission system introduced here is evidently suited mainly for longer-term storage. As noted earlier, the expansion vessels indicated and provide a capability for short term energy storage without the system changing between different operating modes. 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 he assumed constant. Therefore, natural wind variations need not be taken into account. The wind speed is set to a constant 9 m/s.

4.Result and Discussions

The proposed controller design was tested in simulation using MATLAB. The generator model is an Induction generator when we integrated a six (06) of 1.5Mw in transmission network of 120Kv. 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 =.65s, and power active presented the oscillations and stabilized at 1.4s. These oscillations are, consequently, propagated to the power reactive and currents, when they are sagged at t = 0.2s. As a figure 7.0 and figure 8.0 presented the following waveforms of wind turbine characteristics, the speed of wind is fixed at 8m/s, the pitch angle is varied between t =0.1s and 1.2s. This figure shows significantly reduce the torque and reactive power pulsations, while also decreasing the sags factor of the stator current. Also, several steady state simulations were run, with the generator at synchronous speed and rated power.

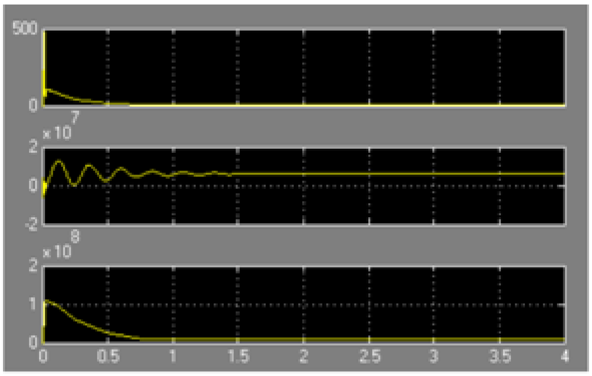

Figure 7.0: waveform of voltage, current, power active and power reactive in power supply connection

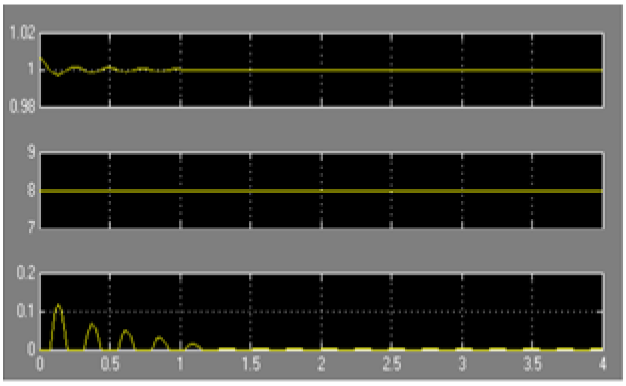

Figure 8.0: waveform of power active, reactive, speed and pitch of turbine and wind speed fixed in 9m/s.

5.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. Aim of this paper is to use wind farm for IG's to compensate the power reactive is presented in when the power fluctuations are eliminates and this confirms the excellent performance of the proposed system for power quality improvement waveform of voltage, current, power active and power reactive in power supply connection.

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