

## Integration of a Wind Turbine Based Doubly Fed Induction Generator Using STATCOM and CROWBAR for Transient Stability Improvement

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### ABSTRACT

Wind power stations mostly placed in remote areas; so they are characterized by weak grids and are often submitted to power system disturbance like faults, voltage sag etc. In this paper the crowbar protection method is used to ride through voltage sags and STATCOM is used to quickly sense the voltage sag and overcome it. The behavior of these machines during grid failure is an important issue. DFIG consists of a common induction generator with slip ring and a partial scale power electronic converter. Indirect field oriented controller is applied to rotor side converter for active power control and voltage regulation of wind turbine. On grid side PQ control scheme is applied. Wind turbine and its control units are described in details and also for STATCOM control. All power system components are simulated in MATLAB/ SIMULINK software. For studying the performance of controller, different abnormal conditions are applied even the worst case. Simulation results prove that the performance of STATCOM and DFIG control schemes as improving power quality and stability of wind turbine.

**Keywords** - STATCOM, PQ control theory, induction machine, PWM, crowbar, rotor side controller, grid side controller, DFIG, wind turbine.

### I. Introduction

To gain sustainable growth and social progress, it is necessary to meet the energy need by utilizing the nonconventional energy resources like wind, biomass, hydro, co generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant [1]. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine[2]

There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity [3]. Today, more than 28000 wind generating turbine plants are successfully operating all over the world [6, 9]. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and

leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. There has to be a protection for such situations [4]. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers [8], harmonics etc. However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system [5]. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Unity power factor at the source side.
- Reactive power support only from STATCOM to wind Generator and Load.
- Simple bang-bang controller for STATCOM to achieve fast dynamic response.

Shunt Flexible AC Transmission System (FACTS) devices, such as the Static Var Compensator (SVC) and the Static Synchronous Compensator (STATCOM), have been widely used to provide high performance steady state and transient voltage control at the Point of Common

Coupling (PCC) [6]. The applications of a SVC or a STATCOM to fixed-speed wind turbines equipped with induction generators have been reported in [7] for steady state voltage regulation, and in [1] for short-term transient voltage stability.

Doubly fed induction generator (DFIG) is one of the most popular wind turbines which includes an induction generator with slip ring, a partial scale power electronic converter and a common DC-link capacitor. Power electronic converter which encompasses a back to back AC-DC- AC voltage source converter has two main parts; grid side source converter (GSC) that rectifies grid voltage and rotor side converter (RSC) which feeds rotor circuit. Power converter only processes slip power therefore it's designed in partial scale and just about 30% of generator rated power [13] which makes it attractive from economical point of view.

## II. Concept of DFIG

The basic layout of a DFIG is shown in fig.1, Doubly fed induction generator is basically a wound rotor induction machine with multi phase wound rotor with multiphase slip rings assembly and brushes enabling access to the rotor. The rotor windings are connected to the grid through an AC-DC-AC converter. The rotor and the grid currents are controlled by controlling the converter. This enables the control of the active power and reactive power flow to the grid from the stator independent of the generator's speed. The number of turns on the rotor of a doubly fed induction generator is 2 to 3 times that of the stator. This means that the rotor voltages are higher and the currents are lower. Therefore in the typical operational speed range of + 30% of the synchronous speed, the converter has to handle lower currents thus reducing the cost of the converter. A doubly fed induction generator has the advantage that power can be imported from or exported to the grid through the power electronics converter. This allows the system to support the grid during severe voltage disturbances thus improving the system stability. By controlling the rotor voltages and currents the synchronization of the machine with the grid is maintained even when the wind speed varies. Under light load conditions, the wind energy is utilized more efficiently than a fixed speed wind turbine. Only 25-30 % of the power is fed to the grid through the converter while the remaining is fed directly to the grid. Due to this reason, the cost of the converter is low and the efficiency of the doubly fed induction generator is good.

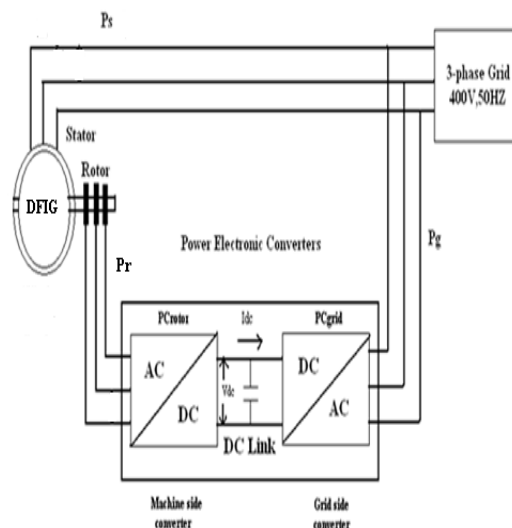


Figure 1 wind turbine driven DFIG

## III. Wind turbine model

The aerodynamic model of a wind turbine can be characterized by the well-known CP-λ-β curves. CP is called power coefficient, which is a function of both tip speed-ratio λ and the blade pitch angle β. The tip-speed-ratio λ is defined by

$$\lambda = \omega t R / v_w \quad (1)$$

where R is the blade length in m, ωt is the wind turbine rotor speed in rad/s, and v<sub>w</sub> is the wind speed in m/s. The CP-λ-β curves depend on the blade design and are given by the wind turbine manufacturer. Given the power coefficient CP, the mechanical power extracted by the turbine from the wind, is calculated by [1], [8]

$$P_w = \frac{1}{2} \rho A C_p(\lambda, \beta) v_w^3$$

where ρ is the air density in kg/m<sup>3</sup>; A<sub>r</sub> = πR<sup>2</sup> is the area in m<sup>2</sup> swept by the rotor blades. At a specific wind speed, there is a unique value of ωt to achieve the maximum power coefficient CP and thereby extract the maximum mechanical (wind) power. If the wind speed is below the rated (maximum) value, the wind turbine operates in the variable speed mode, and the rotational speed is adjusted (by means of active power control in the DFIG) such that the maximum value of CP is achieved. In this operating mode, the wind turbine pitch control is deactivated and the pitch angle β is fixed at 0°. If the wind speed is above the rated value, the rotor speed can no longer be controlled within the limits by increasing the generated power, as this would lead to overloading of the generator and/or the converter. In this situation, the pitch control is activated to increase the wind turbine pitch angle to reduce the mechanical power extracted from wind. Figure 5 shows the structure of

the pitch angle controller [1], [8].  $P_t (= P_s + P_r)$  is the total output active power from the induction generator.

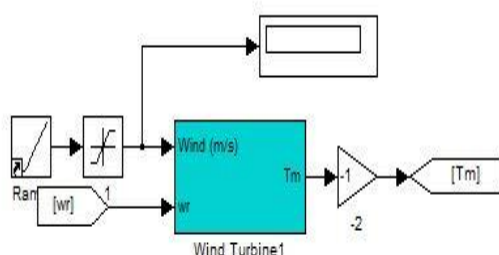


Figure 2. Simulink of wind turbine

#### IV. DFIG with CROWBAR and STATCOM

##### A. Crowbar

To protect the RSC from tripping due to over currents active crowbar is used in the rotor circuit. The crowbar limits the currents and provides a safe path for the currents by short circuiting the rotor by a set of resistors. When the crowbar is activated the RSC pulses are completely disabled and the machine behaves like a squirrel cage induction machine directly coupled to the grid.

The magnetization of the machine that was provided by the RSC during the normal operation is lost and the machine large of amount of reactive power from the grid, which actually grid codes. Though, crowbar circuit triggering produces high stress to the mechanical components of the system crowbar protection is reliable because of its simple construction and low cost.

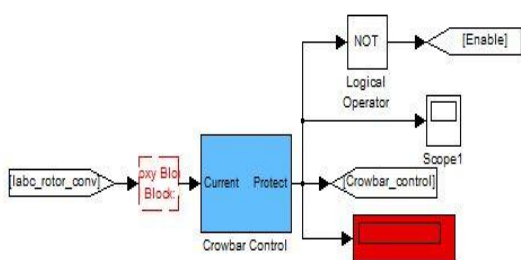


Figure 3. Simulink of Crowbar control

Crowbar protection can be designed with symmetric three phase y-connected resistance. It is connected to the rotor through a controllable breaker. Though, this is not the real case (in reality, the crowbar may be made up of one resistance fed through a switched rectifier bridge), but it may be sufficient to assess the overall impact of a crowbar protection on the LVRT. The breaker is normally open, but it is closed short-circuiting the rotor through the resistance if either the rotor current or the DC-link capacitor voltage becomes too high. At the

same time the switching of the RSC is stopped. The value of the crowbar resistance is chosen as 20 times the rotor resistance. The choice of the crowbar resistance is important because, as it determines how much reactive power the DFIG will draw while the crowbar is inserted. The crowbar is disconnected and the RSC is reinserted when the rotor current and DC-link voltage return to their normal operating range [7].

##### B. Statcom

A STATCOM, also known as an advanced static VAR compensator, is a shunt connected FACTS device. It generates a set of balanced three-phase sinusoidal voltages at fundamental frequency, with rapidly controllable amplitude and phase angle. In this paper, STATCOM is modeled in MATLAB/SIMULINK using an IGBT PWM converter with a dc-link capacitor. The objective of STATCOM is to ride through voltage dip quickly.

#### V. Simulink models

This is the simulink diagram connected with the grid using crowbar protection.

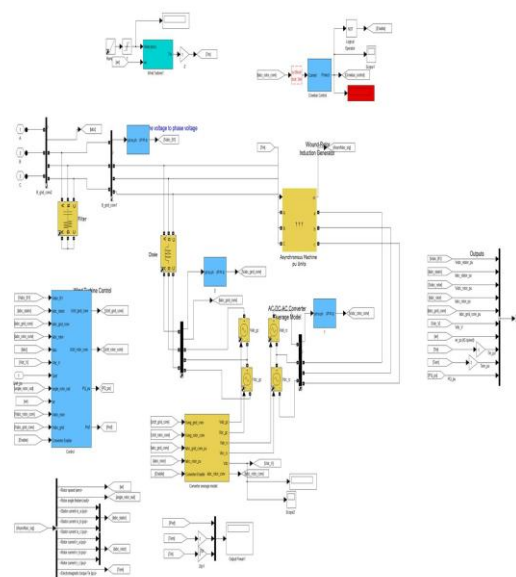


Figure 4. simulink model of wind-grid connected system (1)

This is the simulink diagram connected with the grid using statcom control

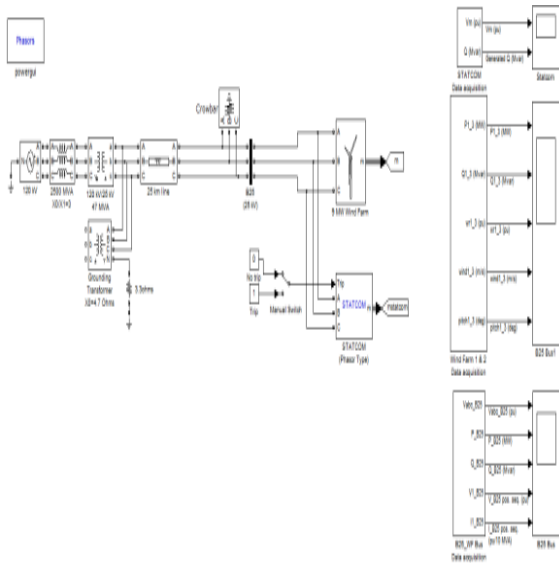


Figure 5. simulink model of wind-grid connected system (2)

### VI. Simulink results

The output of wind power energy system is shown below in which the phase voltages, line currents, active power ,reactive power and rotor speed is shown below.with crowbar and statcom control.

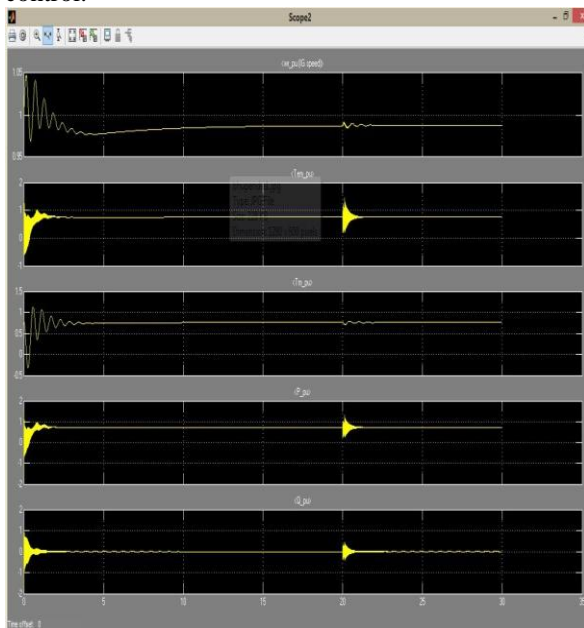


Figure 6. shows the Wind speed , Electrical torque, Mechanical torque , Active power, Reactive power.

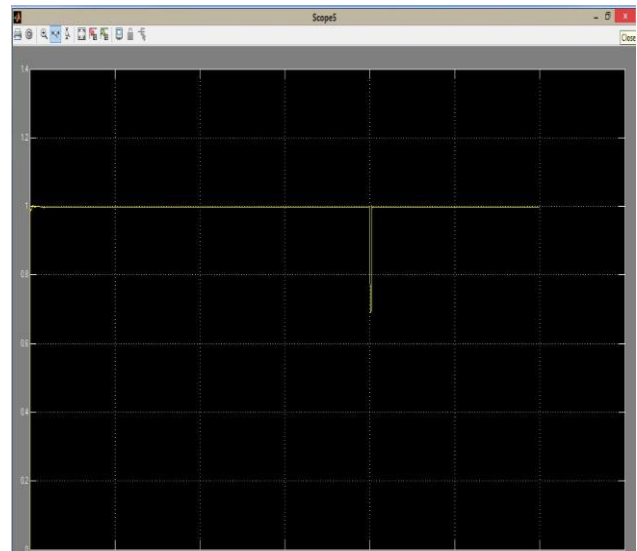


Figure 7.shows stator voltage magnitude and phase.

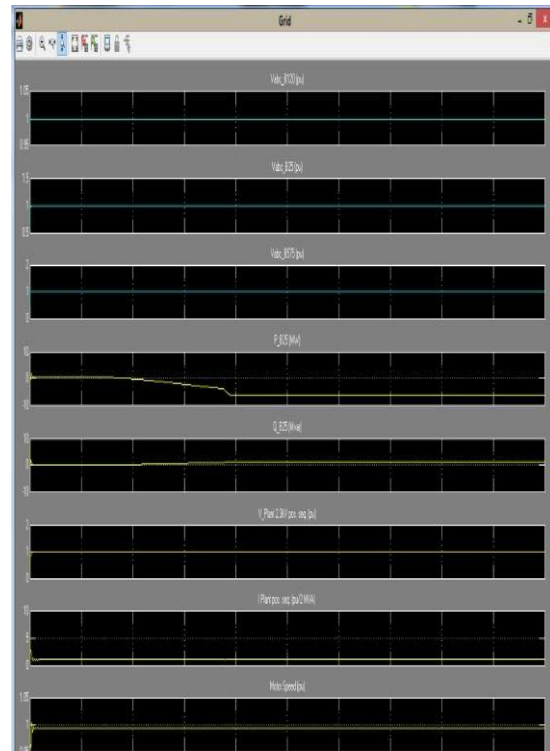


Figure 8.shows (Grid side) Line voltages at buses B120,B25,B575 in pu , Active power, Reactive power, Plant voltage and current ,Motor speed.

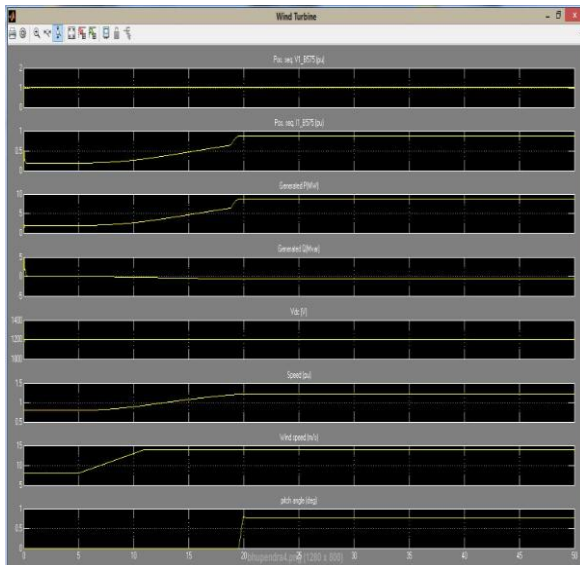


Figure 9.shows(wind turbine side) voltage and current at B575,active and reactive power,turbine speed ,wind speed,pitch angle.

## VII. Conclusion

In this paper, the simulated wind energy system connected with the grid is analyzed with the help of MATLAB/simulink and in this paper the rotor speed, wind speed ,pitch angle, and torque being control to provide the active and reactive power supply. The output of this model gives us a balanced ac supply and reduces the voltage sags and low voltage ride through.

## References

- [1.] CH.Appala Narayana, D.V.N. Ananth, T. Papi Naidu, B. Santosh Kumar, S.Saikiran, I.Prasanna Kumar, Y. Nveen Kumar, K.V. Ramana Application of STATCOM and CROWBAR for Transient Stability Improvement and Performance Enhancement for A Wind Turbine Based Doubly Fed Induction Generator International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-6, January 2013
- [2.] A. D. Thirumorthy, C. Deepthi, Analyzing the Application of Crowbar And Statcom To Overcome Voltage Sags With Actual Field Data International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 3, March 2014)
- [3.] Sannino, "Global power systems for sustainable development," in IEEE General Meeting, Denver, CO, Jun. 2004.
- [4.] K.S Hook, Y. Liu, and S. Atcitty, "Mitigation of the wind generation integration related power quality issues by

energy storage," EPQUJ., vol. XII, no. 2, 2006.

- [5.] R. Billinton and Y. Gao, "Energy conversion system models for adequacy assessment of generating systems incorporating wind energy," IEEE Trans. on E. Conv., vol. 23, no. 1, pp. 163–169,2008,Multistate.
- [6.] D. Tziouvaras, "Relay Performance during Major System Disturbances," in Proc. Protective Relay Engineers, 2007. 60<sup>th</sup> Annual Conference, College Station, TX, 27-29 March 2007, pp. 251-270.
- [7.] J. Manel, "Power electronic system for grid integration of renewable energy source: A survey," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1014, 2006, Carrasco.
- [8.] M. Tsili and S. Papathanassiou, "A review of grid code technology requirements for wind turbine," Proc. IET Renew.power gen., vol. 3,pp. 308–332, 2009.
- [9.] S. Heier, Grid Integration of Wind Energy Conversions. Hoboken, NJ: Wiley, 2007, pp. 256–259.
- [10.] J. J. Gutierrez, J. Ruiz, L. Leturiondo, and A. Lazkano, "Flicker measurement system for wind turbine certification," IEEE Trans. InstrumMeas., vol. 58, no. 2, pp. 375–382, Feb. 2009.
- [11.] Indian Wind Grid Code Draft report on, Jul. 2009, pp. 15–18, CNET.
- [12.] P. Kundur, Power System Stability and Control, McGraw Hill, 1994.
- [13.] Charles Mozina, "Power Plant Protection and Control Strategies for Blackout Avoidance," in Proc. IEEE PES Advanced Metering, Protection, Control, Communication, and Distributed Resources Conference, March 14-17, 2006, pp. 200-218.
- [14.] W. Elmore, Protective Relaying Theory and Applications, CRC Press, 2nd Edition, 2004.
- [15.] Holds worth, L., X.G. Wu, J.B. Ekanayake and N. Jenkins, 2003. Comparison of fixed speed and doubly-fed induction wind turbines during power system disturbances. IEE Proc. Gener. Transm. Distrib., 150 (3): 343-352.