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Analysis of Doubly Fed Induction Generator under Varies Fault Conditions

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Abstract
Wind power stations much placed in remote areas; so they are characterized by weak grids and are often submitted to power system disturbance like faults. In this paper, the behaviour of a wind energy conversion system that uses the structure of Doubly-Fed Induction Generator (DFIG) under faulty conditions is presented. The behavior of these machines during grid failure is an important issue. DFIG consists of an asynchronous machine, in which the stator is connected directly to the grid and its rotor, is connected to the grid via two electronic power converters (back-to-back converter). In the three-phase rectifier and the inverter with IGBTs the Pulse Width Modulation (PWM) and SPWM technique is respectively used. DFIG is analysed and simulated under varies faulty conditions in the environment of MATLAB/SIMULINK.
Index :

I. Introduction

Wind energy technology has experienced important gains over the last few decades [7] due to the technological improvement of wind turbines from fixed speed to variable speed. The Doubly Fed Induction Generator (DFIG) has very attractive characteristics as a wind generator in the fast growing market. The fundamental feature of the DFIG is that the power processed by the power converter is only a fraction of the total power rating, that is, typically (20-30%), and therefore its size, cost and losses are much smaller compared to a full size power converter.

A wind turbine with DFIG uses a frequency converter and a pitch blade actuator to control directly the generator speed and wind turbine output [2]. The frequency converter has the Rotor Side Converter (RSC) and the Grid Side Converter (GSC). The RSC controls independently, active and reactive power, while the GSC also controls the active power flow through the converter by controlling the DC-link voltage to unity.

DFIG can operate at a wider range of speeds depending on the wind speed or other specific operation requirements. Thus, it allows for a better capture of wind energy [6, 11, and 12], and dynamic slip control. Pitch control may contribute to rebuilding the voltage at the wind turbine terminals and maintaining the power system stability after clearance of an external short–circuit fault [2]. In addition, DFIGs have shown better behavior concerning system stability during short–circuit faults in comparison to IG, because of their capability of decoupling the control of output active and reactive power.

The superior dynamic performance of the DFIG results from the frequency converter which typically operates with sampling and switching frequencies of above 2 kHz [1]. At lower voltages, down to 0%, the IGBTs (Insulated Gate Bipolar Transistors) of the DFIG are switched off and the system remains in standby mode [8-10, and 12]. If the voltages are above a certain threshold value during fault, the DFIG system is very quickly synchronized and is back in operation again.

DFIG can operate in both sub-synchronous and super-synchronous operation mode to impart power to the grid or from the grid with a minimum rotor power input in both stead and variable speed wind turbine operation mode.

In this paper the dynamic behavior of a 1.5 MW wind farm is modelled using MATLAB. The behaviour of the system for a single line to ground fault is analyzed.

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.

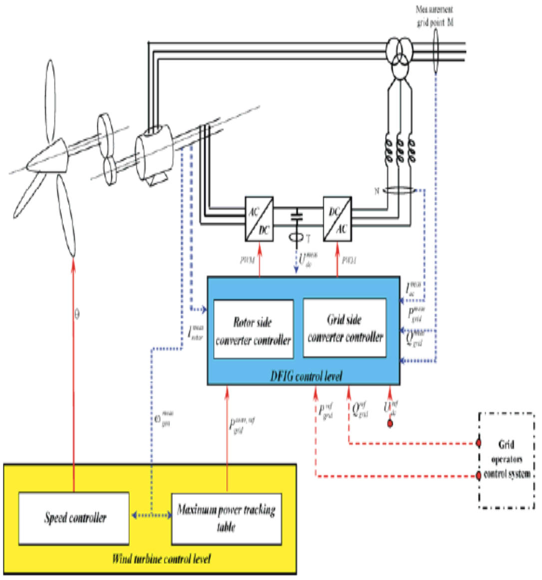


Figure. 1: Doubly fed induction generator.

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.

III. Wind Turbine Model

It is well-known that the relation between the wind speed and aerodynamic power is described by the following equation:

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

and the corresponding torque is expressed as

$$T_w = \frac{1}{2}\rho\pi R^3 v_w^2 \frac{C_p(\lambda,\beta)}{\lambda}$$

where *Pw* is the aerodynamic power extracted from the wind [W], *Tw* is the corresponding aerodynamic torque [Nm], ρ the air density [kg/m3], *R* the wind turbine rotor radius [m], *vw* the equivalent wind speed [m/s], β the pitch angle of rotor [deg], *Cp* the power coefficient with its maximum value at 0.59 (Betz limit) and λ is the tip speed ratio given by the following equation:

$$\lambda = \frac{\omega_{wt} R}{v_w}$$

Where W_{wt} is the wind turbine rotor speed [rad/s]

IV. Back-to-Back Converter

4.1 Rotor side converter (RSC)

Rotor side converter acts as a PWM rectifier during the machine working in super synchronous mode and as an inverter during sub synchronous mode. The purpose of the rotor side converter's control is the independent control of the rotor's active and reactive power. To succeed it, the voltages and the currents are transformed in d-, q- synchronously reference frame, where the d-axis is aligned with the air gap's flux vector.

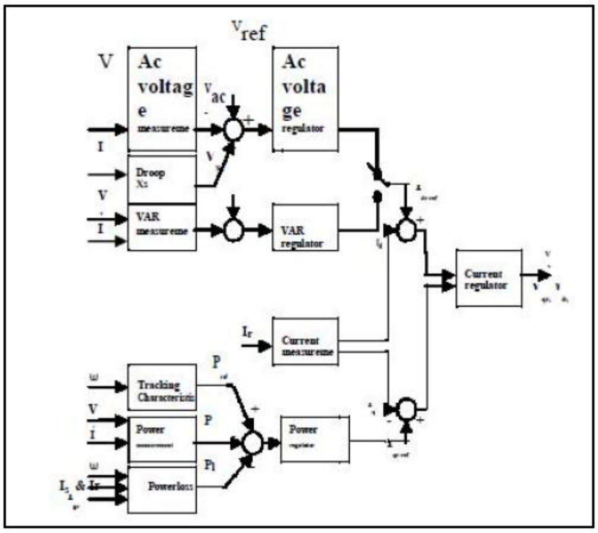


Figure 2: Rotor side converter control system

4.2 Grid Side Converter (GSC)

The grid side converter acts as a PWM inverter during the machine working in super synchronous mode and as a rectifier during sub synchronous mode. In sub synchronous mode, the rotor's power is coming from the capacitor of the DC link, so the voltage interconnection is dropped down. This leads to power transportation from the grid to the capacitor. In super synchronous mode the rotor feeds the capacitor, its voltage increases and the grid side converter transfers active power to the grid. Moreover, the reactive power that is exchanged between grid side converter and the grid, can be controlled. In our case the upper IGBTs of the GSC are always off, while the corresponding parallel diodes conduct.

The control of this converter is achieved by transforming the three phase quantities to d-, q- synchronously frame, in which the d-axis is aligned with the vector of the grid's voltage, because grid's voltage is constant.

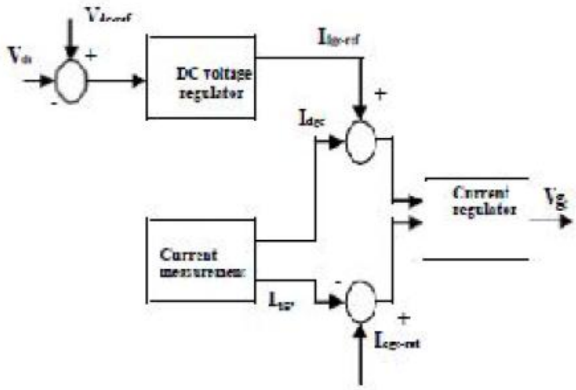


Figure 3: Grid side converter control system.

The converter Cgrid is used to regulate the voltage of the DC bus capacitor. In addition, this model allows using Cgrid converter to generate or absorb reactive power. The system consists of an outer regulation loop consisting of a DC voltage regulator. The output of the DC voltage regulator is the reference current Idgc_ref for the current regulator. The inner current regulation loop consists of a current regulator. The current regulatory controls the magnitude and phase of the voltage generated by converter Cgrid (Vgc) from the Idgc_ref produced by the DC voltage regulator and specified Iq_ref reference. The current regulator is assisted by feed forward terms which predict the Cgrid output voltage.

V. Simulation Results

A 9 MW DFIG is simulated using MATLAB/Simulink. As shown in figure.4 of simulink model of doubly fed induction generator under fault condition. A three phase fault is created at the generator terminal at t=0.1s and cleared at t =0.15s.Fig.5 shows the voltage and current waveforms at the generator terminal and close to MV bus. During the fault, voltages of all three phases reach ver y low values as sho wn in F i g . 5. Ideally this should reach to zero, but in practice, there will be some fault resistance and hence will have a ver y small magnitude voltage values. Generator terminal current will suddenly increase at the instant of fault initiation followed by a rapid decay as determined by the transient impedance of the generator.

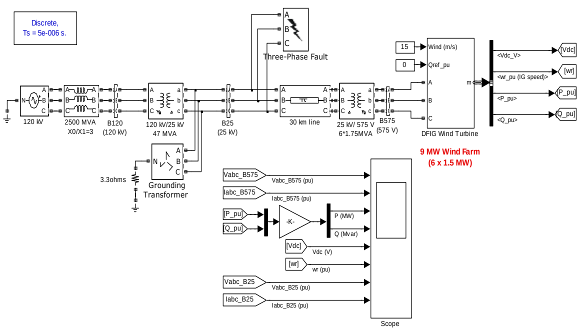


Figure 4: Simulink model of DFIG under faults.

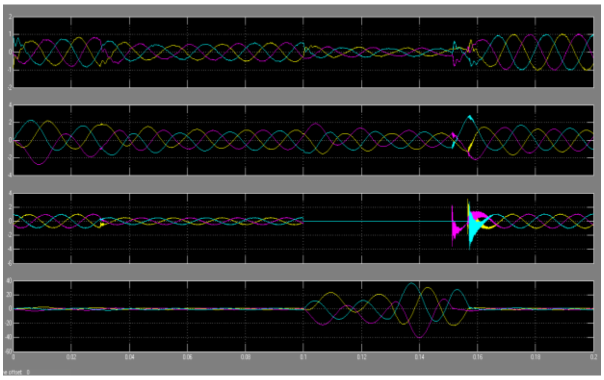


Figure 5: Three phase to Ground fault (a) Voltage at DFIG (b) Current at DFIG (c) Voltage at Line (d) Currents at Line.

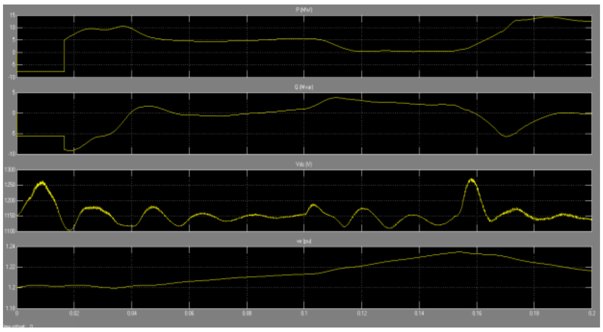


Figure 6: (a) Active power (b) Reactive power (c) V_{dc} (d) Turbine speed (W_r).

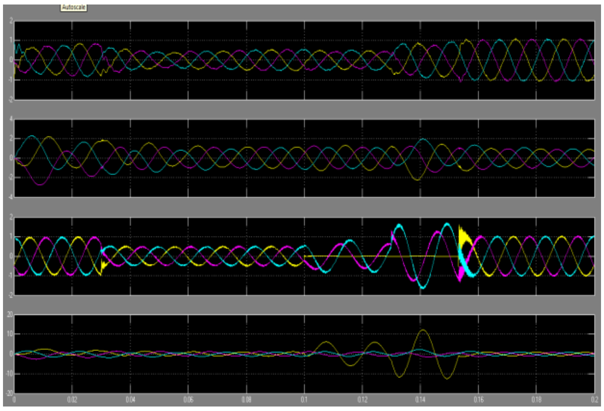


Figure 7: Single phase to Ground fault (a) Voltage at DFIG (b) Current at DFIG (c) Voltage at Line (d) current at DFIG

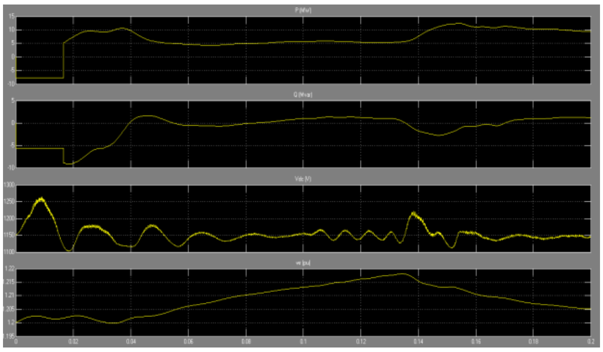


Figure 8: (a) Active power (b) Reactive power (c) V_{dc} (d) Turbine speed (W_r).

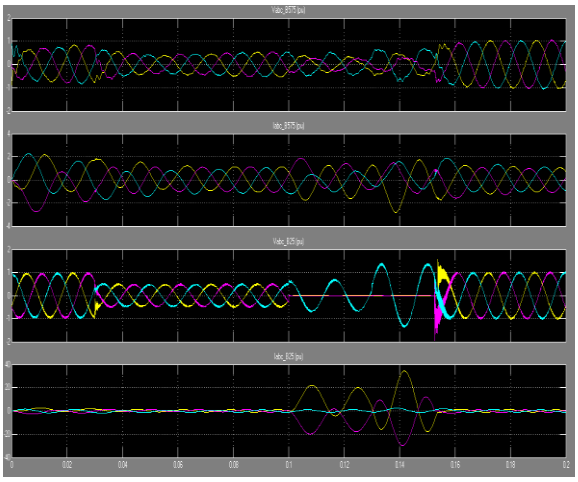


Figure 9: Two phase to ground faul (a) Voltage at DFIG (b) Current at DFIG (c) Voltage at Line (d) Currents at Line.

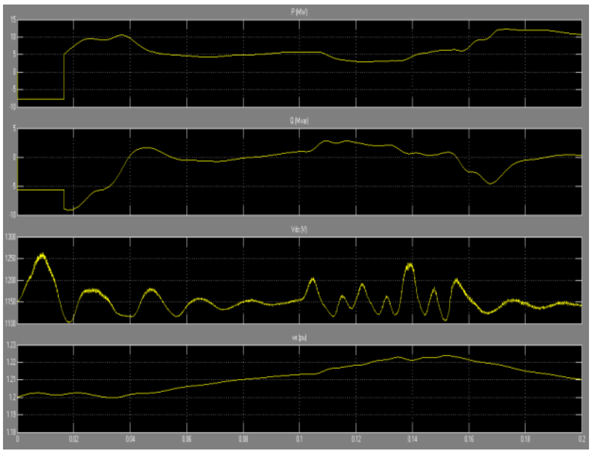


Figure 10: (a) Active power (b) Reactive power (c) V_{dc} (d) Turbine speed (W_r).

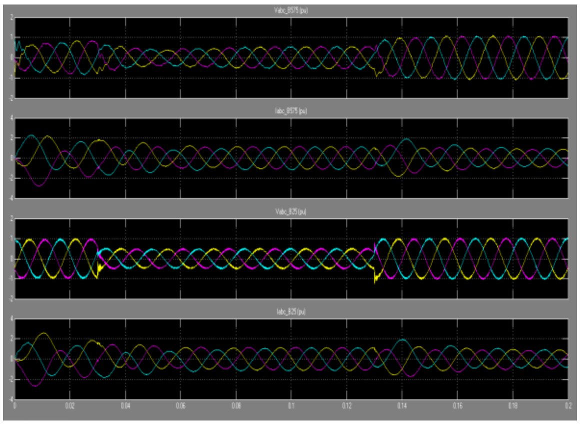


Figure 11: Without any fault in DFIG (a) Voltage at DFIG (b) Current at DFIG (c) Voltage at Line (d) Currents at Line.

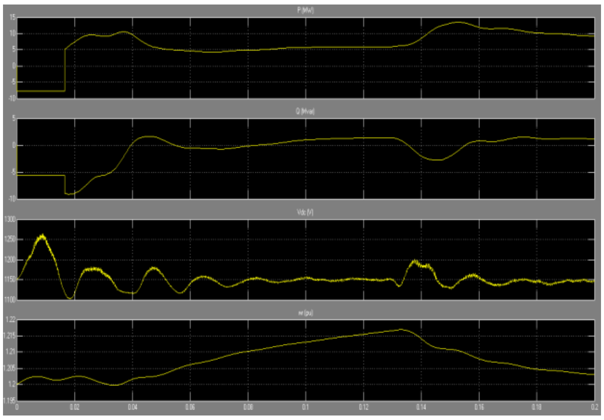
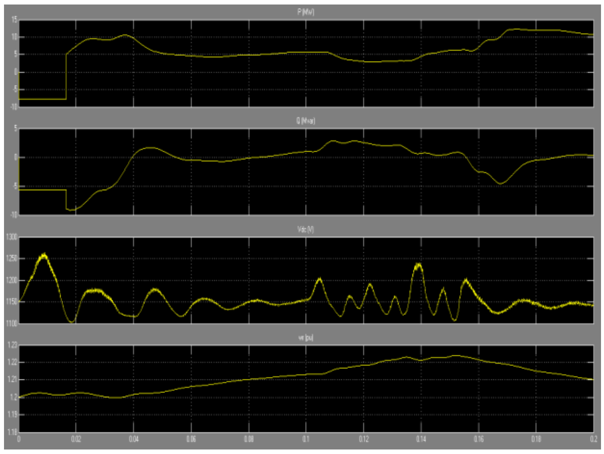


Figure 10: Without any fault condition (a) Active power (b) Reactive power (c) V_{dc} (d) Turbine speed (W_r).



In this paper 9 MW wind farm is modelled using MATLAB. The effect of Phase to Ground Fault in phase A is analyzed for the 9 MW doubly fed Induction Generator wind farm unit and similarly two phase to ground fault and three phase fault. Even though the per unit value fells the system will recover it. In case Line to Line fault occurs the system will recover it up to 0.5 p.u voltage drop (drips it) and increases the Active power and decrease the reactive power. This gives the profitable operation and the interconnected systems are protected.

VI. Conclusion

In this paper a variable speed wind generation system based on DFIG under power system disturbance has been simulated and a suitable controller is designed to supply the deficit reactive power to the grid and help in grid recovery. By as the generator and converter stay connected, the synchronism of operation remain established during and after the fault and normal operation can be continued immediately after the fault has been cleared. Here the reactive power is being supplied to the grid during longer duration voltage dips in order to facilitate voltage restoration. Proper controller designed is adopted to improve the transient and dynamic performance of DFIG coupled Wind turbine under these abnormal grid conditions. This paper analyzes the DFIG transient behavior and control possibility under grid disturbances like fault and large voltage dips etc. In this model, with the help of only one rotor side converter we are able to control the active and reactive power and maintain the stability of grid under faulty conditions.

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Biography

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