International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:6, No:6, 2012

# Simulation Study of DFIG Wind Turbine under Grid Fault

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***Abstract*—**During recent years wind turbine technology has undergone rapid developments. Growth in size and the optimization of wind turbines has enabled wind energy to become increasingly competitive with conventional energy sources. As a result today’s wind turbines participate actively in the power production of several countries around the world. These developments raise a number of challenges to be dealt with now and in the future. The penetration of wind energy in the grid raises questions about the compatibility of the wind turbine power production with the grid. In particular, the contribution to grid stability, power quality and behavior during fault situations plays therefore as important a role as the reliability. In the present work, we addressed two fault situations that have shown their influence on the generator and the behavior of the wind over the defects which are briefly discussed based on simulation results.

***Keywords*—**Doubly fed induction generator (DFIG), Wind energy, grid fault

## I. INTRODUCTION

WIND energy generation equipment is most often installed in remote, rural areas. These remote areas usually have weak grids, often with voltage unbalances and under voltage conditions. When the stator phase voltages supplied by the grid are unbalanced, the torque produced by the induction generator is not constant. Instead, the torque has periodic pulsations at twice the grid frequency, which can result in acoustic noise at low levels and at high levels can damage the rotor shaft, gearbox, or blade assembly [1], [2]. Also an induction generator connected to an unbalanced grid will draw unbalanced current. These unbalanced current tend to magnify the grid voltage unbalance and cause over current problems as well Wind energy has been the subject of much recent research and development. In order to overcome the problems associated with fixed speed wind turbine system and to maximize the wind energy capture, many new wind farms will employ variable speed wind turbine. DFIG (Double Fed Induction Generator) is one of the components of Variable speed wind turbine system. DFIG offers several advantages when compared with fixed speed generators including speed control. These merits are primarily achieved via control of the rotor side converter. Many works have been proposed for studying the behavior of DFIG based wind turbine system connected to the grid. Most existing models widely use vector control Double Fed Induction Generator. The stator is directly connected to the grid and the rotor is fed to magnetize the machine. [3], [4]

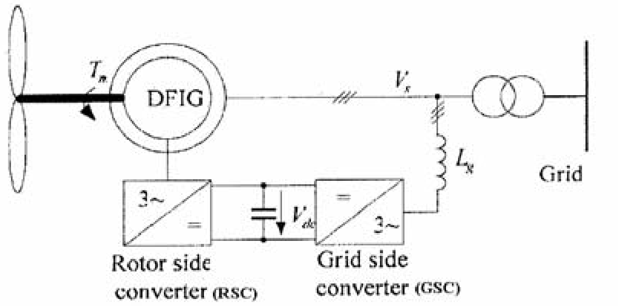

Fig. 1 A typical Grid connected WT based on DFIG

## II. TURBINE MODELING

A wind turbine can be characterized by the non dimensional curve of power coefficient $Cp$ as a function of Tip-Speed Ratio (TSR) $\lambda$, where, $\lambda$ is given in terms of rotor speed, $\omega_m$ (rad/s), wind speed, $V$ (m/s), and rotor radius, $R$ (m) as:

$$\lambda = \frac{R\omega_m}{V} \tag{1}$$

Wind turbine power coefficient, $C_P$ is dependent upon $\lambda$. If pitch angle, $\beta$ is incorporated, $C_P$ becomes a function of $\boldsymbol{\lambda}$ and β, i.e. $C_p = f(\boldsymbol{\lambda}, \beta)$. The power coefficient as a function of  and β can be expressed as [6]:

$$C_p = 0{,}22\left(\frac{116}{\lambda'} - 0{,}4\beta - 5\right)e^{-\frac{12{,}5}{\lambda'}} \tag{2}$$

here,

$$\frac{1}{\lambda'} = \frac{1}{\lambda + 0{,}08\beta} - \frac{0{,}035}{\beta^3 + 1} \tag{3}$$

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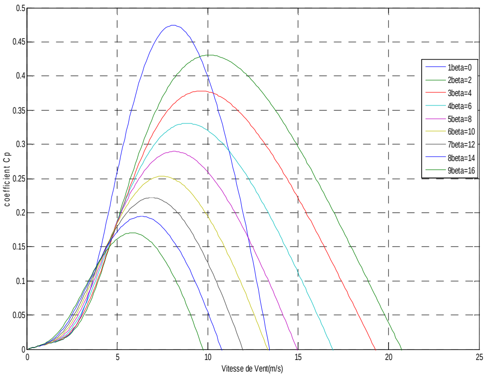


Fig. 2 Power coefficient as a function of tip speed ratio and pitch angle

The $C_p = f(\boldsymbol{\lambda}, \beta)$ curves for some β values are shown in Fig. 2. It can be seen that as β increases, $C_p$ decreases, thus reducing the power produced by the Wind Turbine.

The mechanical output power of the wind turbine can be expressed as:

$$P_{aer} = \frac{1}{2} C_p(\lambda, \beta) \rho S V^3 \tag{4}$$

where, $\rho$ is the air density (kg.m-3) and $S$ is the rotor rotational area, i.e., $\pi R^2$

## III. Dynamic Model Of DFIG

In order to investigate the actual behavior of the DFIG, dynamic equation needs to be considered for more realistic observation. From the point of view of the control of the machine, the *dq* representation of an induction machine leads to control flexibility. The dynamic behavior of the DFIG in synchronous reference frame can be represented by the Park equations provided all the rotor quantities are referred to the stator side. The stator and rotor voltages are expressed as follows:

$$V_{ds} = R_s I_{ds} + \frac{d\phi_{ds}}{dt} - \phi_{qs}\omega_s \tag{5}$$

$$V_{qs} = R_s I_{qs} + \frac{d\phi_{qs}}{dt} + \phi_{ds}\omega_s \tag{6}$$

$$V_{dr} = R_r I_{dr} + \frac{d\phi_{dr}}{dt} - \phi_{qr}(\omega_s - \omega_r) \tag{7}$$

$$V_{qr} = R_r I_{qr} + \frac{d\phi_{qr}}{dt} + \phi_{dr}(\omega_s - \omega_r) \tag{8}$$

The flux linkage equations of the stator and rotor can be related to their currents and are expressed as follows:

$$\phi_{ds} = L_s I_{ds} + M I_{dr} \tag{9}$$

$$\phi_{qs} = L_s I_{qs} + M I_{qr} \tag{10}$$

$$\phi_{dr} = L_r I_{dr} + M I_{ds} \tag{11}$$

$$\phi_{qr} = L_r I_{qr} + M I_{qs} \tag{12}$$

This electrical model is completed by the mechanical equation:

$$C_{mec} = J\frac{d\Omega}{dt} + K_f \Omega + C_r \tag{13}$$

where the electromagnetic torque $C_{em}$ can be written as a function of stator fluxes and rotor currents:

$$C_{em} = p\frac{M}{L_r}(\phi_{dr} I_{qs} - \phi_{qr} I_{ds}) \tag{14}$$

In the coordinate two-phase, the active powers of e reactive stator asynchronous generator written:

$$P_s = V_{ds} I_{ds} + V_{qs} I_{qs} \tag{15}$$

$$Q_s = V_{qs} I_{ds} + V_{ds} I_{qs} \tag{16}$$

## IV. INDUCTION GENERATOR UNBALANCE EFFECTS

Unbalance may be defined as in several views it can be voltage dip is a sudden reduction (between 10% and 90%) of the voltage at a point in the electrical system, and sudden change of load (dynamic load) .There can be many causes for a voltage dip: short circuits somewhere in the grid, switching operations associated with a temporary disconnection of a supply, the flow of the heavy currents that are caused by the start of large motor loads, or large currents drawn by arc furnaces or by transformer saturation. Voltage dips due to short-circuit faults cause the majority of equipment trip and therefore of most interest. Faults are either symmetrical (three-phase or three phase-to-ground faults) or nonsymmetrical (single-phase or double-phase or double-phase-to ground faults). Depending on the type of fault, the magnitudes of the voltage dips of each phase might be equal (symmetrical fault) or unequal (nonsymmetrical faults). The magnitude of a voltage dip at a certain point in the system depends mainly on the type of the fault, the distance to the fault, the system configuration, and the fault impedance. [5]

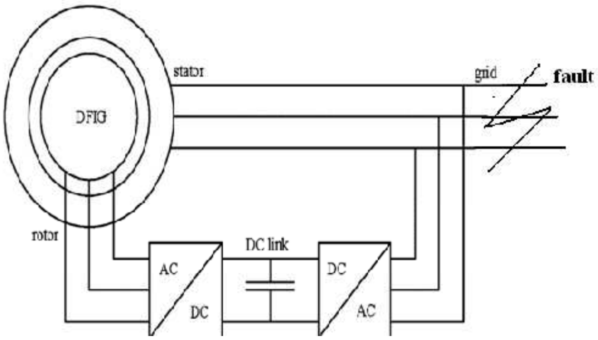


Fig. 3 block diagram of DFIG with fault in grid side

## V. SIMULATION AND RESULTS

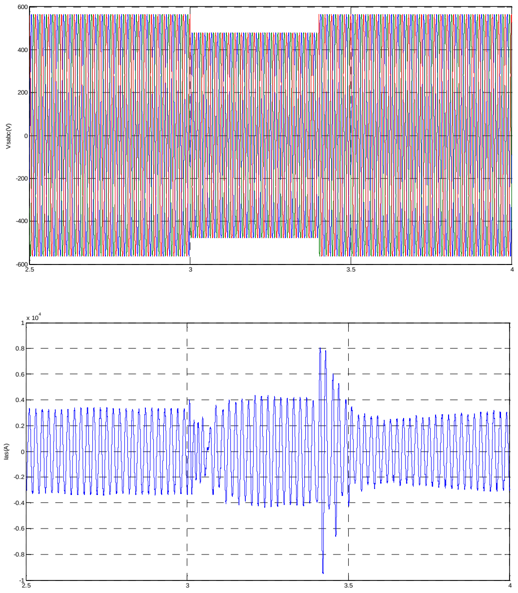


Fig. 4 Voltage and current stator during voltage dip

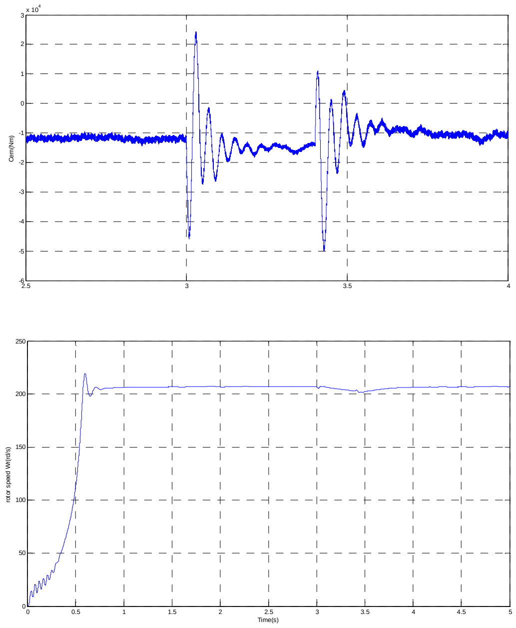
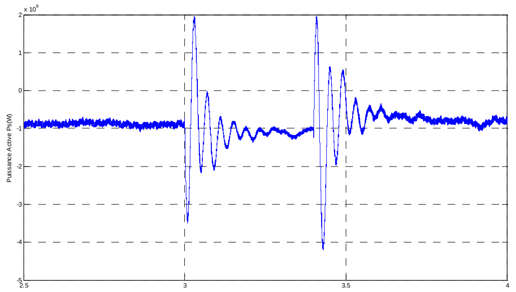


Fig. 5 Torque and speed during voltage dip



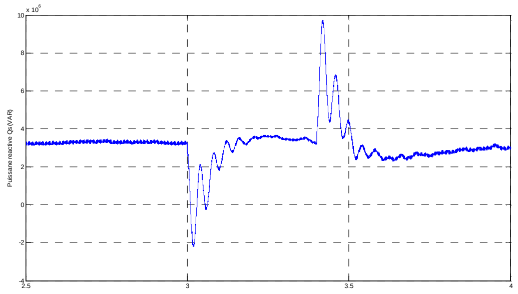


Fig. 6 Active power and reactive power during voltage dip

To study the influence of voltage sags on electrical and mechanical parameters, we applied a three-phase voltage sag of 20% and duration of 0.5 s at the DFIG. Since the duration of the fault is small compared to fluctuations in wind speed, then the wind speed is considered constant during the network fault. Immediately after failure to appear at t = 3s, the generator voltage drops, as shown in Fig. 4. The voltage dip leads to oscillations of the current imbalance stotorique and transitional

In Fig. 5 shows that the DFIG electromagnetic torque oscillates also because of the voltage dip. After a voltage dip, the torque generated is reduced. As wind energy has not changed during the voltage dip, the rotor will accelerate due to the mismatch between the mechanical and electromagnetic torque.

## VI. CONCLUSION

The DFIG considered in this analysis is an induction generator with wound rotor rings. The stator is directly connected to the grid and the rotor is linked to the grid through a static converter. In this study, the dynamic DFIG is presented for abnormal conditions of the electrical network. It is found that during the disruption of the network, a large oscillation of torque which results in pulsating torques which may cause a stall and the DFIG system in the chain of transmission

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