



## FAULT ANALYSIS OF DOUBLY FED INDUCTION GENERATOR BASED WIND ENERGY CONVERSION SYSTEM

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**Abstract-fault analysis is a major criterion for the efficient operation of every machine. During fault there is a variation in voltage and current wave forms. Also there is a variation in active and reactive power flow. In this paper discussing about DFIG based wind energy power system and having specifications as follows, 3kw, 490v, 50 Hz. Here the faults consider are three phase to ground fault and single phase to ground fault. Results are verified using MATLAB.**

**Index terms- doubly fed induction generator (DFIG), wind turbine (WT), grid side converter (GSC), rotor side converter (RSC).**

### I. INTRODUCTION

Wind energy generation is under renewable energy source it is a feasible solution to energy shortage. China has the most installed wind energy capacity, followed by the United States, Germany, Spain and India. Wind energy is one of the fastest growing energy production industries at present situation and it will continue to grow worldwide, as many countries have plans for future development. The Indian wind energy sector has an installed capacity of 18.55 GW. However the output power of wind generator is fluctuating due to wind speed variations. This will causes serious problems in the distribution network. Wind turbines can either operate at fixed speed or variable speed. Because of the advantages of the DFIG over other generators it is being used for most of the wind power applications. DFIG wind turbines dominate the market due to cost-effective provision of variable-speed operation.

DFIG is the most advanced method of generating electrical energy from the wind. This chapter introduces the operation and control of a

Doubly-fed Induction Generator (DFIG) system. The DFIG is currently the system of choice for multi-MW wind turbines. The aerodynamic system must be capable of operating over a wide wind speed range in order to achieve optimum aerodynamic efficiency by tracking the optimum tip-speed ratio.

There are different kinds of faults are associated with the electrical system .mainly classified in to symmetrical faults and asymmetrical faults. In this project consider the symmetrical faults to study the behavior of DFIG based wind energy conversion system .The stator circuit is directly connected to the grid while the rotor winding is connected via slip-rings to a three-phase converter. For variable-speed systems where the speed ranges requirements are small, for example  $\pm 30\%$  of synchronous speed. Doubly fed induction generator (DFIG) is the most prominent generator for WT applications due to its improved economic efficiency, flexibility to control the active and reactive powers with partly rated converters, reduced mechanical stresses, improved power quality, and lower operating noise.

An AC-DC-AC converter is included in the induction generator rotor circuit. The power electronic converters need only be rated to handle a fraction of the total power – the rotor power – typically about 30% nominal generator power. Therefore, the losses in the power electronic converter can be reduced, compared to a system where the converter has to handle the entire power, and the system cost is lower due to the partially-rated power electronics. This chapter will introduce the basic features and normal operation of DFIG systems during different grid faults.

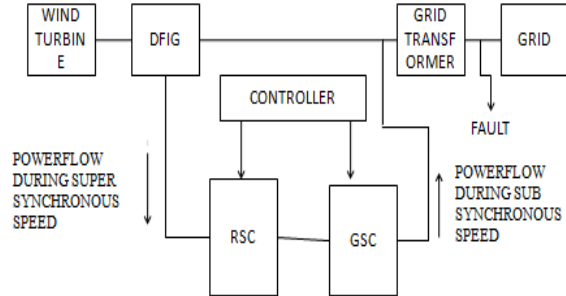


Figure 1-block diagram

## II. SYSTEM CONTROL

### 2.1 The Rotor-Side Converter Control

RSC provides the excitation for the induction machine rotor. With this PWM converter it is possible to control the torque hence the speed of the DFIG and also the power factor at the stator terminals. Fig 2.1 shows the rotor side rotor-side converter control which provides a varying excitation frequency depending on the wind speed conditions. The induction machine is controlled in a synchronously rotating  $dq$ -axis frame, with the  $d$ -axis oriented along the stator-flux vector position in one common implementation. This is called stator-flux orientation (SFO) vector control. In this way, a decoupled control between the electrical torque and the rotor excitation current is obtained. Consequently, the active power and reactive power are controlled independently from each other. There are other options for directional rotating frames. Orientation frames applied in traditional vector control of induction machines such as rotor-flux orientation and magnetizing-flux orientation can also be utilised. Additionally, the stator voltage orientation (SVO) is also commonly-used in DFIG vector controller, as contrast with SFO. To describe the control scheme, the general Park's model of an induction machine is introduced. Using the motor convention in a static stator-oriented reference frame, without saturation, the voltage vector equations are

$$\vec{v}_s = R_s \vec{i}_s + \frac{d\vec{\varphi}_s}{dt} \quad (2.1)$$

$$\vec{v}_r = R_r \vec{i}_r + \frac{d\vec{\varphi}_r}{dt} - j\omega \vec{\varphi}_r \quad (2.2)$$

Where  $s$  is the slip and  $v_f$  is the stator voltage imposed by the grid. The rotor voltage  $v_r$  is controlled by the rotor-side converter and used to perform generator control. The flux vector equations are

$$\vec{\varphi}_s = L_s \vec{i}_s + L_m \vec{i}_r \quad (2.3)$$

$$\vec{\varphi}_r = L_m \vec{i}_s + L_r \vec{i}_r \quad (2.4)$$

where  $L_s$  and  $L_r$  are the stator and rotor self-inductances:  $L_s = L_m + L_{ls}$ ,  $L_r = L_m + L_{lr}$ .

Under stator-flux orientation (SFO), in  $dq$ -axis component form, the stator flux equations are:

$$\varphi_{sd} = L_s i_{sd} + L_m i_{rd} = \varphi_s = L_m i_{ms} \quad (2.5)$$

The rotor voltage and flux equations are (scaled to be numerically equal to the ac per-phase values)

$$v_{rd} = R_r i_{rd} + \sigma L_r \frac{di_{rd}}{dt} + \omega_{slip} \sigma L_r i_{rq} \quad (2.6)$$

$$v_{rq} = R_r i_{rq} + \sigma L_r \frac{di_{rq}}{dt} + \omega_{slip} (L_o i_{ms} + \sigma L_r i_{rd}) \quad (2.7)$$

$$\varphi_{rd} = \frac{L_m^2}{L_s} i_{ms} + \sigma L_r i_{rd} \quad (2.8)$$

$$\varphi_{rq} = \sigma L_r i_{rq} \quad (2.9)$$

Where the slip angular speed is  $\omega_{slip} = \omega_s - \omega_r$

$$\varphi_{s\alpha} = \int (v_{s\alpha} - R_s i_{s\alpha}) dt \quad (2.10)$$

$$\varphi_{s\beta} = \int (v_{s\beta} - R_s i_{s\beta}) dt \quad (2.11)$$

$$\theta_s = \tan^{-1} \left( \frac{\varphi_{s\beta}}{\varphi_{s\alpha}} \right) \quad (2.12)$$

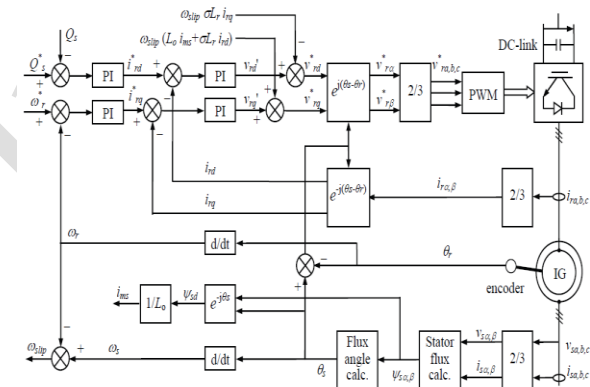


Figure 2.1- control structure for rotor side converter From the rotor voltage equations

$$v'_{rd} = R_r i_{rd} + \sigma L_r \frac{di_{rd}}{dt} \quad (2.13)$$

$$v'_{rq} = R_r i_{rq} + \sigma L_r \frac{di_{rq}}{dt} \quad (2.14)$$

To ensure good tracking of the rotor  $dq$ -axis currents, compensation terms are added to  $v'_{rd}$  and  $v'_{rq}$  to obtain the reference voltages  $v_{rd}^*$  and  $v_{rq}^*$  according to

$$v_{rd}^* = v'_{rd} + \omega_{slip} \sigma L_r \quad (2.15)$$

$$v_{rq}^* = v'_{rq} + \omega_{slip} (L_m i_{ms} + \sigma L_r i_{rd}) \quad (2.16)$$

where  $\theta_s$  is the stator-flux vector position. The control scheme of the rotor-side converter is organised in a generic way with two series of two PI-controllers schematic block. The reference  $q$ -axis rotor current  $i_{rq}^*$  can be obtained either from an outer speed control loop or from a reference torque



### III. SIMULATION MODELS AND RESULT

#### A. Turbine Model

Here the model of wind turbine is done by considering the wind speed as 15m/s. The value of pitch angle taken is zero. The turbine shaft is connecting with the drive train. The transfer function modeling of drive train is done. There is a feedback circuit between the wind turbine and drive train. The output shaft torque is given to the input port of DFIG

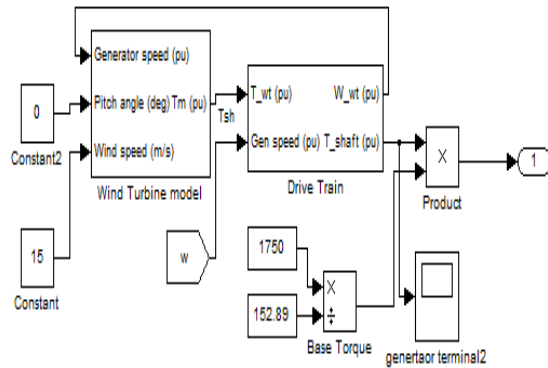


Figure 3.1- Turbine model

#### B. Ac-Dc-Ac Converter Model

This is a bidirectional converter. These have two DC-AC converter section. This is Converting DC in to AC voltage at the both end. This will give constant value of voltage. There is a DC link for getting constant dc voltage. One converter section is connecting to the rotor side converter and another converter section is connected to the rotor side converter. Each converter section is made up of 6 pulse IGBTs. Here employing pulse width modulation technique. Each of the controller pulses are giving to the pulse generator. This will generate suitable pulse according to the controller signal. The output of this generator is giving to the gate side of switches for the each converter section

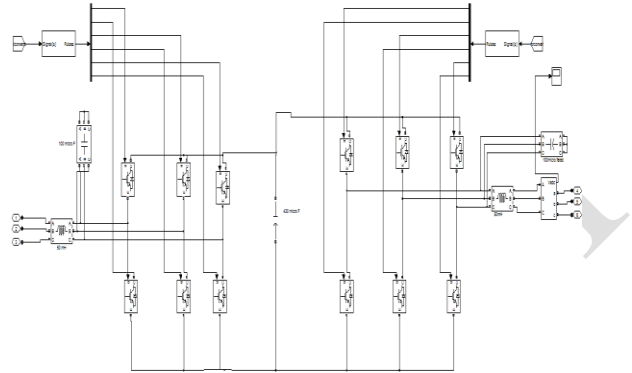


Figure 4.4-AC-DC-AC converter model

#### C. DFIG Based Wind Turbine Model during Fault

In Figure 3.4 DFIG based wind energy conversion with fault at grid side is modeled here. The generator rating is 3Kw, 490volt, 50Hz frequency. Within the entire system there is a AC-DC-AC converter, Tuning circuit, transformer of rating 500/1000volt. At the grid side there is a load connected to the secondary of transformer winding. The fault signal is generated by three phase fault generator. By using this single phase and three phase faults are generated. The controller circuit for rotor side converter and grid side converter are provided here. The switching operation of the AC-DC-AC, IGBTs controlled by this controllers. Scopes are provided at the necessary areas.

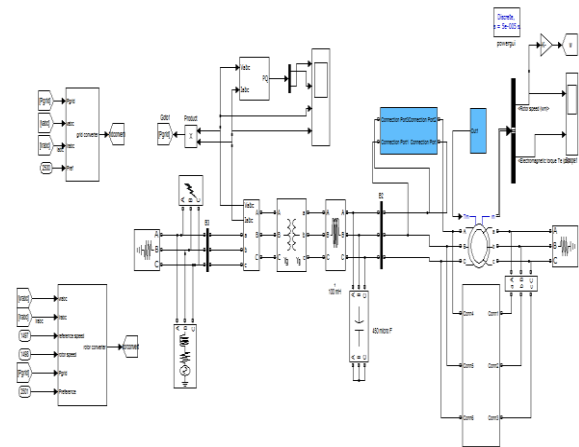


Figure 3.4-DFIG based wind turbine model

#### IV. SIMULATION OUTPUT RESULT

##### A. Turbine Torque

The Figure 4.1 shows that the turbine torque is negative; this shows that DFIG is operating as generator.

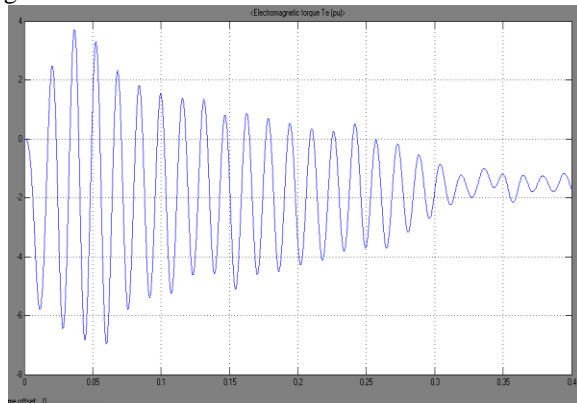


Figure 4.1-turbine torque out put

##### B. DFIG Output

The Figure 4.2 shows the output waveform of given DFIG system. This shows the line voltage, line current, and power output of the DFIG, this is measured during normal operating conditions. At this condition there is no fault at the grid side.

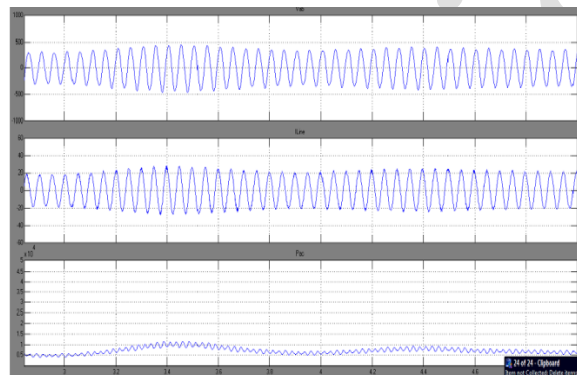


Figure 4.2 DFIG line voltage, line current, power output

##### C. Waveform during Single Phase Fault

Output of given DFIG system during fault at the grid side shown in Figure 4.3. Here is giving a single phase fault at the grid side. Then measured the voltage, current, active power, and reactive power. During this fault one of the phase voltage become zero, and corresponding current exceeds the normal value

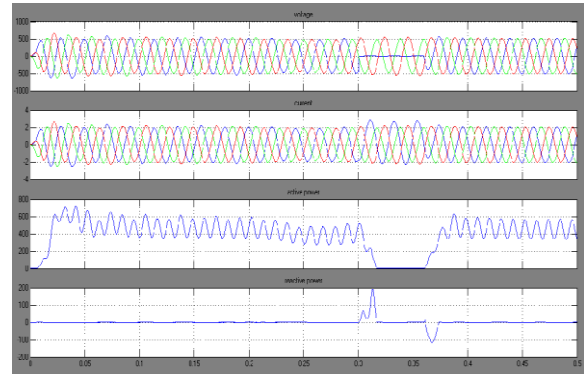


Figure 4.3- DFIG output during 1phase fault

##### D. Waveform during Three Phase Fault

Figure 4.4 shows the measurement of voltage, current, active power, and reactive power during the three phase fault at the grid side. In this condition the three phase voltage become zero for short duration

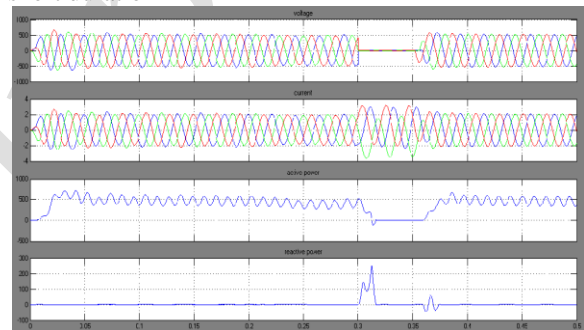


Figure 4.4 -DFIG output during 3 phase fault

#### V. CONCLUSION

This thesis studies the operation of DFIG based wind turbine during the fault. The modeling and working operation of DFIG wind systems are explained here. During the fault at the grid side, the variation in the active and reactive power are disused here. From the wave forms it is clear that DFIG is good in active and reactive power compensation during the fault at grid side. Using the MATLAB software results is verified.

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