International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 4, Issue 1 (July 2014) PP: 11-17

Matlab Modeling and Simulation of DFIG with Dump Resistor during Faulty Condition

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Abstract: *In this paper the phenomenon of a DFIG during fault is described. Here a three phase fault is created by using fault block in MATLAB Simulink library and the converter which was connected at the rotor side of the DFIG(Doubly Fed Induction generator) is disconnected after the fault and is shorted by resistances. Then the rotor is no longer supplied from the voltage source inverter. Here the operation of both normal or fault duty is described. The assumption is that the mechanical system cannot respond during the short time of a three phased short circuit. Here equivalent circuits are built to model the fault response of DFIG.*
Keywords: *DFIG, dump resistance, equivalent circuit, faulty condition.*

I. Introduction

Now a days the demand of Electrical energy is increasing day by day, but the presence of fossils fuel is limited. We need to find some another source of energy. On the other hand during the power generation process from thermal or fossil fuel a huge amount of pollutant is emitted ,which is harmful for our environment. So, non conventional source of energy has come into importance to generate power or to produce green energy. At present wind power is the fastest growing power generation technology in India and it accounts for around 70% of total grid-interactive renewable capacity in the Country. Wind energy dominates India's renewable energy industry, accounting for installed capacity of 14 GW. Doubly-fed induction generator (DFIG) wind turbines are used widely by all the wind generator manufacturers as they are of variable speed wind turbine. The speed of wind may not be fixed throughout the day abd we know the frequency of generated power is dependent upon the rotational speed of the turbine of the generator. So we use variable speed turbine and that is Doubly Fed Induction Generator. In this paper during fault time the conditions and one of the protections of DFIG is described.

II. Present Scenario

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world. In 2009-10 India's growth rate was highest among the other top four countries. As of 31 December 2013 the installed capacity of wind power in India was 20149 MW, mainly spread across Tamil Nadu (7154 MW),Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka (2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power. India's wind atlas is available. The worldwide installed capacity of wind power reached 283 GW by the end of 2012. China (75,564 MW), US (60,007 MW), Germany (31,332 MW) and Spain (22,796 MW) are ahead of India in fifth position. The short gestation periods for installing wind turbines, and the increasing reliability and performance of wind energy machines has made wind power a favoured choice for capacity addition in India.

III. Doubly Fed Induction Generator (DFIG)

DFIG is called variable speed wind turbine. In this case, mechanical power at the machine shaft is converted into electrical power supplied to the ac power network via both the stator and rotor windings. Furthermore, the machine operates like a synchronous generator whose synchronous speed (i.e., the speed at which the generator shaft must rotate to generate power at the ac power network frequency f Network) can be varied by adjusting the frequency of the ac currents fed into the rotor windings. In a conventional three-phase synchronous generator, when an external source of mechanical power (i.e., a prime mover) makes the rotor of the generator rotate, the static magnetic field created by the dc current fed into the generator rotor winding rotates at the same speed (n Rotor) as the rotor. As a

$$f_{Stator} = \frac{n_{Rotor} \times N_{Poles}}{120}$$

Where, f_{stator} is the frequency of the ac voltages induced across the stator windings of the doubly-fed induction generator, expressed in hertz (Hz). A doubly fed induction machine is basically a standard, wound rotor induction machine with its stator windings directly connected to the grid and its rotor windings connected to the grid and its rotor windings connected to the grid through a converter. The AC/DC/AC
converter is divided to two components: the rotor side converter and the grid side converter. These converters are voltage sourced converters that use force commutated power electronic devices to synthesize an AC Voltage from a DC source.

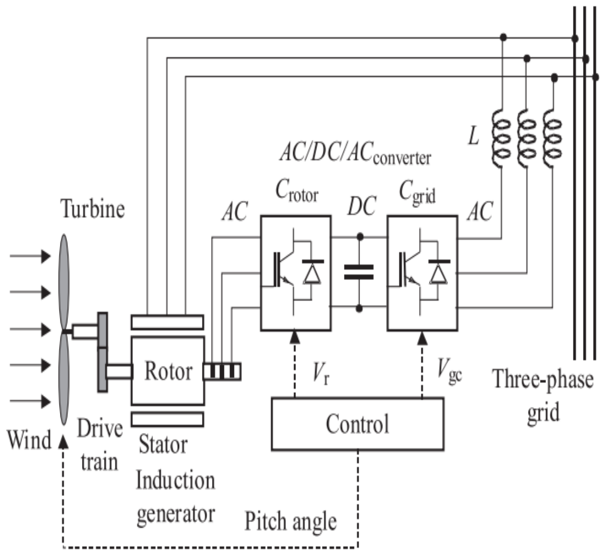

Fig.1 Wind Energy Conversion System

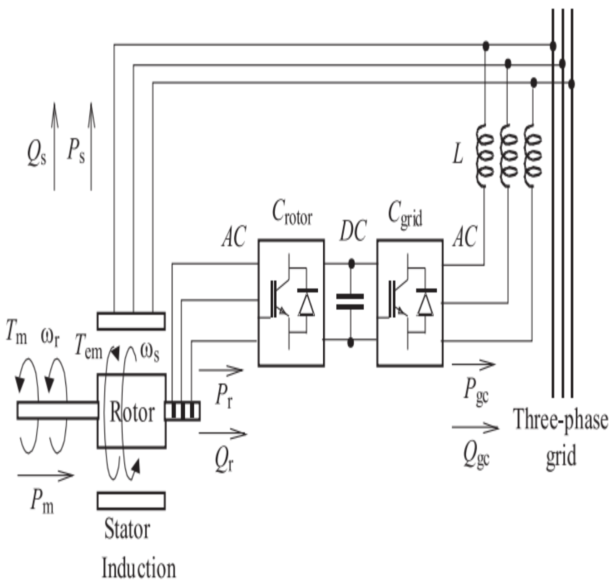

Fig.2 Power flow in a DFIG

A capacitor connected on the DC side acts as the DC voltage source. A coupling inductor is used to connect the grid side converter to the grid. Figure 2 shows the Power flow in a DFIG. Generally the absolute value of slip is much lower than 1 and consequently the rotor electrical power output Pr is only a fraction of stator real power output Ps. For super synchronous speed operation, Pr is transmitted to DC bus capacitor and tends to raise the DC voltage. For sub synchronous speed operation, Pr is taken out of the DC bus capacitor and tends to decrease the DC bus voltage.

The grid side converter is used to generate or absorb the grid electrical power P_{gc} in order to keep the DC voltage constant.

IV. System Description

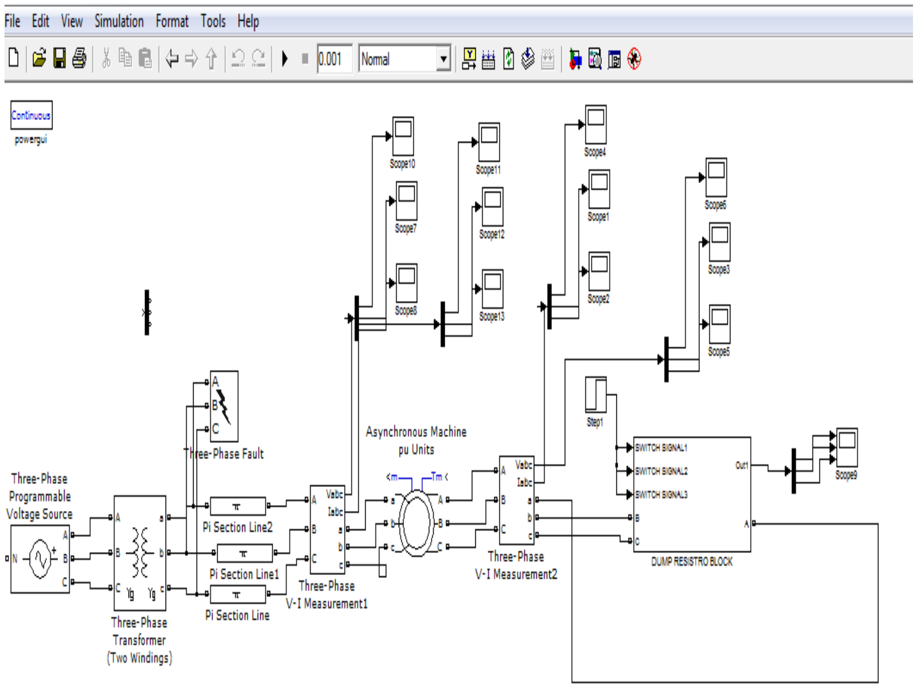

Fig:3 complete system

The system operates in two modes.

a) Normal duty and
b) Fault condition.

A. Normal Duty:

In Figure the normal duty connection diagram of the generator system is shown. The rotor of the generator is connected to the rotor side converter through switch K. in the actual setup, K is a switch converter.

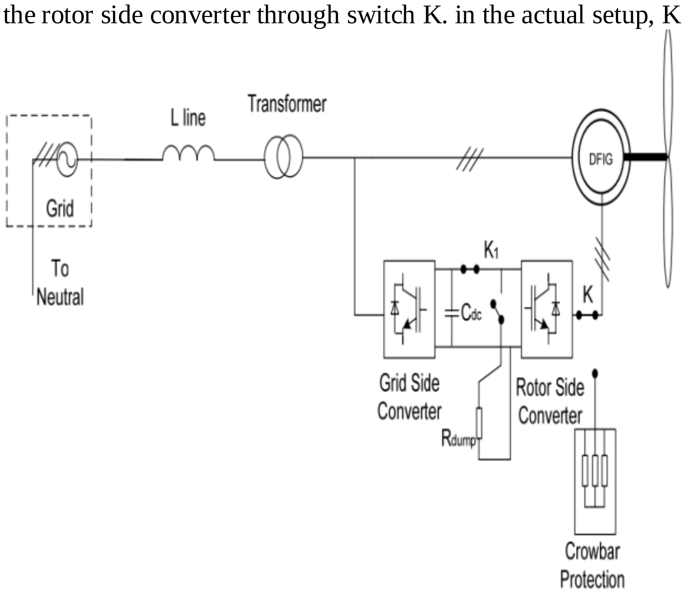

Fig. 4, Normal duty operation

The crowbar protection is also depicted in the figure 4. By switch K, the resistor bank may be connected to the rotor windings. This is activated when a fault occurs and transients are so high that the generator must be protected by short-circuiting the rotor. The normal duty equivalent circuit is shown in figure below.

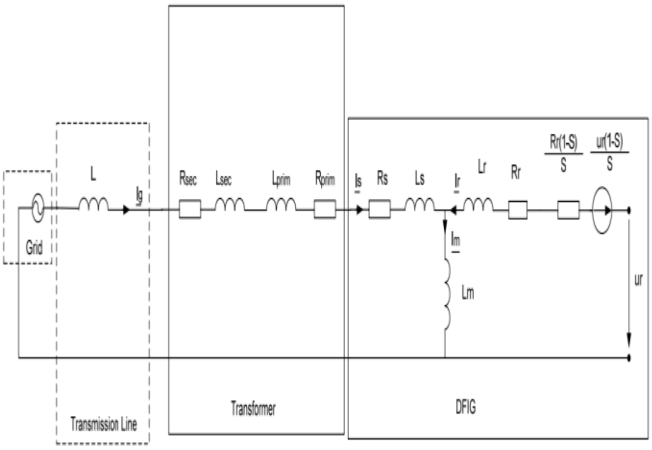

Fig:5, The normal duty equivalent circuit

Equations derived from, Figure 5 are presented in the following:
The first circuit loop comprising the grid voltage u g the equivalent inductance L_{ech} and resistance R_{ech}. By omitting the magnetising branch of the transformer, the primary and secondary elements being connected in series may be reduced to equivalent components below.

$U_g = R_{ech}\, i_g + \frac{dLec\,h}{dt}\, ig + \frac{dLm}{dt}\, i_m$

The detailed formulas for the equivalent resistance and inductance are presented in the following:

$R_{ech} = R_{sec} + R_{prim} + R_s$

Where
R_{sec} – resistance of the secondary side of the transformer
R_{prim}– resistance of the primary side of the transformer
R_s– stator resistance of the machine.

$L_{ech} = L_{sec} + L_{prim} + L_{line} + L_s$
L_{sec} – inductance of the secondary side of the transformer
L_{prim} – inductance of the primary side of the transformer
L_{line} – line parasitic inductance
L_s – stator inductance

The second circuit loop equation comprises the rotor voltage and the slip dependent elements:
$U_r = R_a\, i_r + \frac{d\Psi r}{dt} - \frac{Ur\,(1-S)}{S}$
where
R_a- rotor equivalent resistor.
S-slip
Ψ r – rotor flux
$Ra = Rr + \frac{Rr\,(1-S)}{S}$
The rotor flux is:
$\Psi_r = L_r\, i_r + L_m\, i_s$
If the slip is considered constant, the rotor resistor value would incorporate the slip value component for a given slip. This assumption is acceptable for the fault situations presented in the following.

B. Fault Condition

When a fault occurs on a transmission line, over-currents flow in the system. The protection system of the wind generator has the role to limit the short circuit current. The converter is disconnected from the circuit and connected to a load resistor. The diagram of the fault and protection is depicted in Figure.

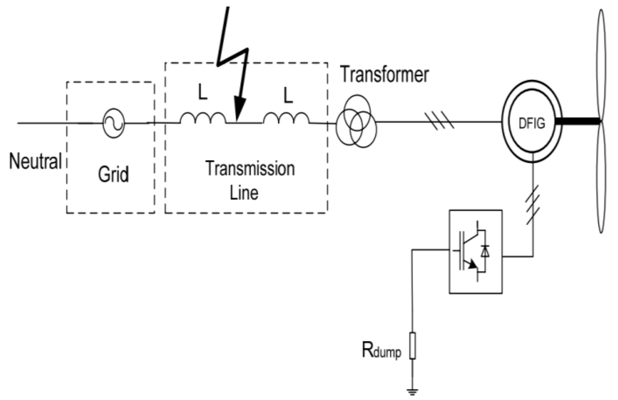

Fig: 6,Under faulty condition

When a short circuit occurs and the current rises, the voltage drops at constant power. Based on this, capacitors in the circuit may be neglected. The rotor is no longer supplied from the voltage source inverter. Instead, it is connected to the dump resistor through a commutator. The equivalent circuit is shown below:

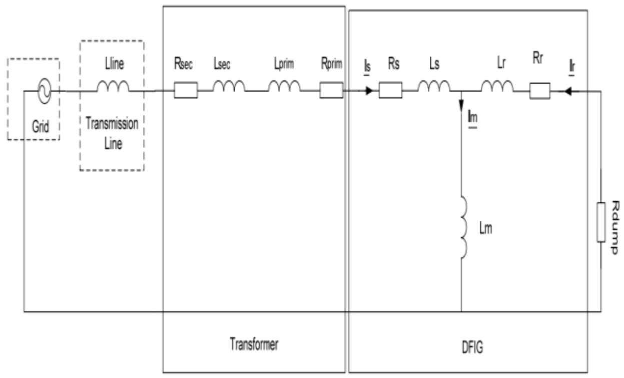

Fig: 7, equivalent circuit when resistance is connected.

The magnetisation branch of the transformer was neglected on the grounds that the current flowing through it is low. The series inductances and resistances cannot be neglected as values of the corresponding impedances rise with the current.

V. Simulation Model

Figure shows the main simulation model of the dump resistor protection.
Main model:

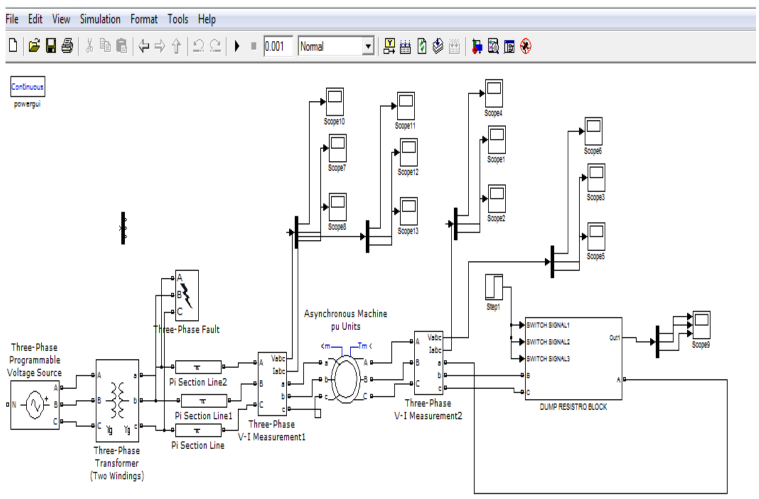

Fig:8

Dump Resistor block:

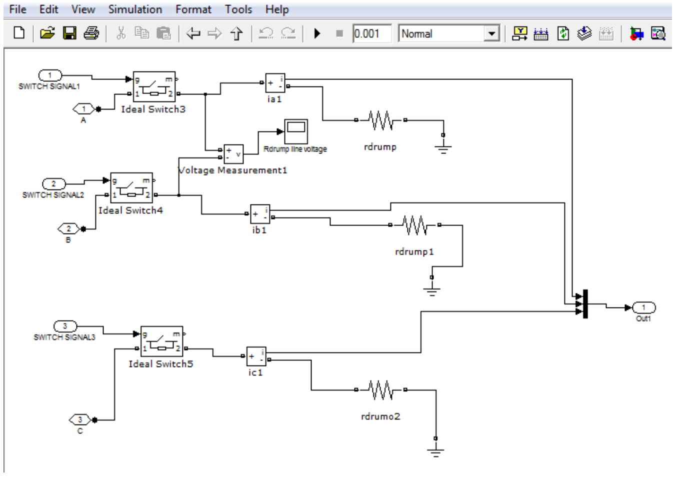

Fig:9

VI. Simulation Results

In the following, simulation results are presented. In Figure dump resistor simulation results from the model is presented. The area of interest is between 0.2 and 03 seconds. This is the time interval in which the fault is active.

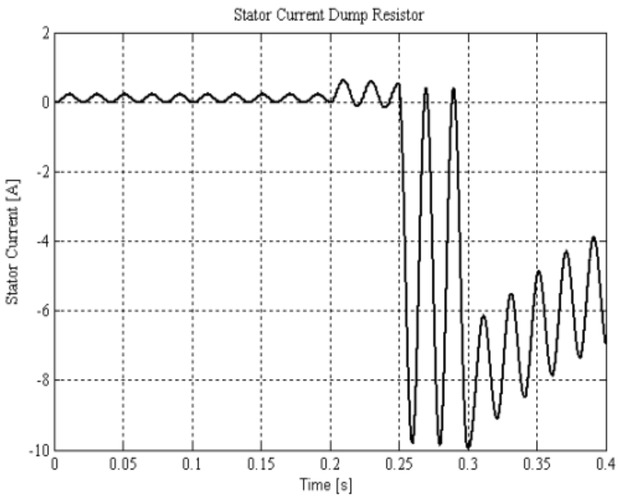

Fig:10, Stator current vs simulation time.

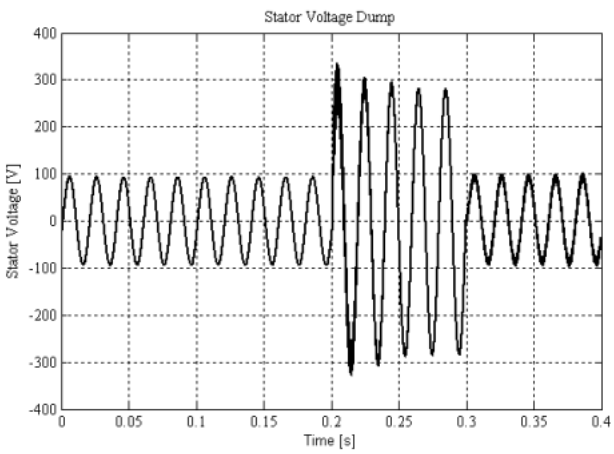

Fig:11,Stator voltage vs simulation time

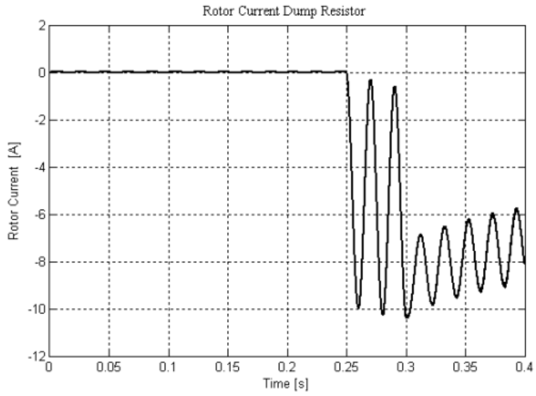

Fig: 12,Rotor current vs simulation time

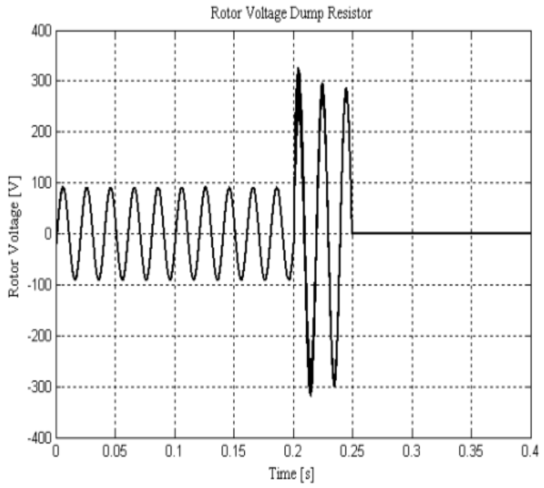

Fig:13,Rotor voltage vs simulation time.

In Figure 10 stator current of phase A and phase to ground voltage are presented. The Protection response may be viewed during the second half of the fault. The stator current increases when the additional resistors are connected. The voltage is decreasing as shown in Figure 11. The rotor current and voltage are shown in Figure 12. One may observe that after connecting the protection, the voltage is greatly reduced. However, residual voltage may still be seen until the fault subsides at 0.3s.

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