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DYNAMIC MODELING OF DFIG BASED WIND ENERGY CONVERSION SYSTEMS

M.Ramesh[1], T.R.Jyothsna[2]

Abstract- From the past few years, people are realizing that renewable energy resource are sustainable energy resources because of environmental pollution and power shortage problems. With deep penetration in wind energy into the various networks, vigorous studies are carried out on DFIG based variable speed wind turbine to find out the integration between wind energy farms and power systems. These systems require accurate models of doubly fed induction generator wind turbines and their associated modeling. In this paper a dynamic model of DFIG has been derived, which can be used to simulate the DFIG wind turbine representation of the generator stator and rotor circuits.
Keywords –DFIG, variable speed, Dynamic model

1. INTRODUCTION

Because of environmental pollution and power shortage people are planning to implement energy resource programs in various governments in different countries. So many countries are recognized the importance of renewable energy resources. In that wind is one of the best sustainable sources of energy. In the past few years, the importance of Wind power has been penetrated into power grids. Many classifications are made to develop the wind turbine techniques. Now, doubly fed induction generator based wind turbine is becoming so familiar [1]; DFIG WT has the advantages of economic in construction, flexible control and high transfer energy efficiency, and three phase winding of the stator is directly connected to the grid , and three phase windings of the rotor is connected to the converters through slip rings. Because of supplying of exciting current from converters to the DFIG, the rating of converters in DFIG is considerably low and which is 20-25% of rating of DFIG. Flexibility of control in DFIG can be achieved by using IGBT based converters and these controllers can impact on stability of the system [2],[3].

This paper will be organized as follows. First, Section II describes the dynamic modeling of the DFIG and rotor side converter. Then, the control schemes for the RSC, using feedback linearization technique and its detailed analysis of input output linearization is presented and Implementation of internal dynamics of the rotor side converter through voltage control is given in section III. Simulation results are showcased in Section IV. Finally, section V summarizes the conclusions.

2. DOUBLY FED INDUCTION GENETAROES

2.1 Doubly Fed Induction Generator model

A schematic diagram of a Doubly Fed Induction Generator based wind turbine is shown in Fig.1. It consists of wind turbine, back to back converters with DC link. The back to back converters are connected to the DFIG rotor and other end is connected to the grid. Power transition among rotor and grid side converters can be controlled by adjusting the control signals of IGBT legs in converters [4], [5], [6]. This scheme acts as a adjustable voltage source to the rotor [7], [8]. The dynamic model of DFIG is fairly contained with three sub models, including the wind turbine model, the transmission mechanism model and the generator model [9] .

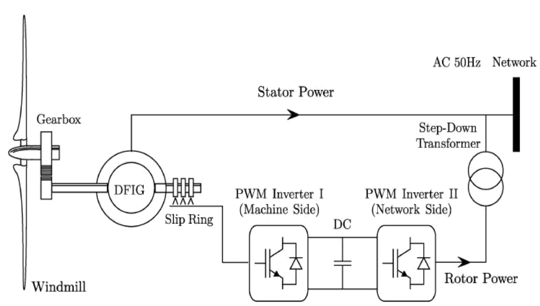


Fig.1 Scheme of a DFIG equipped wind turbine.

[1] Department of Electrical Engineering, Andhra University College of Engineering (A), Visakhapatnam, A.P, India
[2] Department of Electrical Engineering, Andhra University College of Engineering (A), Visakhapatnam, A.P, India

2.2 Wind turbine modelling

For converting wind energy to mechanical energy wind turbine is used. Wind turbine output power is stated as followed based on the principle of aerodynamics:

$$P_t = \frac{1}{2}\rho\pi R^2 V_v{}^3 C_p \tag{1}$$

$$T_t = \frac{1}{2}\rho\pi R^3 V_v{}^2 C_t \tag{2}$$

2.3 Transmission Mechanism model

A reduced design of drive train is achieved by neglecting the damping and stiffness of the shaft. In this model, only one single inertia is measured as summation of inertia of turbine and inertia of rotor and equivalent torque based equation is stated as follows:

$$Tem - Tload = J\frac{d\Omega_m}{dt} \tag{3}$$

Based on assumptions the one-mass model of the shaft in wind system is stiff and other constructed moving parts are lumped together.

2.4 Generator model

The dynamic analysis of a Doubly Fed Induction Generator is done by using □-β and the d – q model[14],[15]. Variables of stator and rotor are related with relevant reference frames in this model which can deal the characteristics in more realistic way. The generator model of DFIG can be expressed by voltage equations, power and electromagnetic torque equations under the □-β coordinate system [14],[16].

Voltage Equations:

$$V_{\alpha s} = R_s i_{\alpha s} + p.\varphi_{\alpha s} \tag{4}$$

$$V_{\beta s} = R_s i_{\beta s} + p.\varphi_{\beta s} \tag{5}$$

$$V_{\alpha r} = R_r i_{\alpha r} + p.\varphi_{\alpha r} + \omega_r * \varphi_{\beta r} \tag{6}$$

$$V_{\beta r} = R_r i_{\beta r} + p.\varphi_{\beta r} - \omega_r * \varphi_{\alpha r} \tag{7}$$

Power Equations:

$$P_s = \frac{3}{2}(V_{\alpha s}\, i_{\alpha s} + V_{\beta s} i_{\beta s}) \tag{8}$$

$$P_r = \frac{3}{2}(V_{\alpha r}\, i_{\alpha r} + V_{\beta r} i_{\beta r}) \tag{9}$$

$$Q_s = \frac{3}{2}(V_{\beta s}\, i_{\alpha s} - V_{\alpha s} i_{\beta s}) \tag{10}$$

$$Q_r = \frac{3}{2}(V_{\beta r}\, i_{\alpha r} - V_{\alpha r} i_{\beta r}) \tag{11}$$

Electromagnetic Torque Equation:

$$T_{em} = \frac{3}{2} p(\varphi_{\beta r} i_{\alpha r} - \varphi_{\alpha r} i_{\beta r}) \qquad (12)$$

3. D_Q MODELING

In doubly fed induction generator, flux linkage is chosen as basic variable for representing [17],[18] the d-q axis used for simulation. This representation is based on two axis full-order known as the Park model [10]. There is an equivalent two-axis representation of three axis. In that stator direct axis is represented as ds and quadrature axis is represented as qs, and Rotor direct axis is represented as dr and rotor quadrature axis is represented as qr. Here a synchronously rotating reference frame chosen as d-q reference frame which is rotating at synchronous speed. There by interaction among electromagnetic torque and current in rotor is observed. In this model three-phase quantities are changed to the two-phase quantities [11],[12].The generator model of DFIG can be expressed by voltage equations, power and electromagnetic torque equations under the d-q coordinate system.

3.1 Voltage Equations:

- $V_{ds} = R_s i_{ds} + \frac{d\varphi_{ds}}{dt} \quad j\omega_s \varphi_{qs}$ (13)

+ j $V_{qs} = R_s i_{qs} + \frac{d\varphi_{qs}}{dt} \quad \omega_s \varphi_{ds}$ (14)

+ j $V_{dr} = R_r i_{dr} + \frac{d\varphi_{dr}}{dt} \quad (\omega_s - \omega_m)\varphi_{qr}$ (15)

- j $V_{qr} = R_r i_{qr} + \frac{d\varphi_{qr}}{dt} \quad (\omega_s - \omega_m)\varphi_{dr}$ (16)

3.2 Flux linkage Equations:

$$\varphi_{ds} = L_s i_{ds} + L_m i_{dr} \qquad (17)$$

$$\varphi_{qs} = L_s i_{qs} + L_m i_{qr} \qquad (18)$$

$$\varphi_{dr} = L_r i_{dr} + L_m i_{ds} \qquad (19)$$

$$\varphi_{qr} = L_r i_{qr} + L_m i_{qs} \qquad (20)$$

3.3 Electromagnetic Torque Equation:

$$T_{em} = \frac{3}{2} p \frac{L_m}{L_s} (\varphi_{qs} i_{dr} - \varphi_{ds} i_{qr}) \qquad (21)$$

3.4 Power Equations:

$$P_s = \frac{3}{2}(V_{\alpha s} i_{\alpha s} + V_{\beta s} i_{\beta s}) \qquad (22)$$

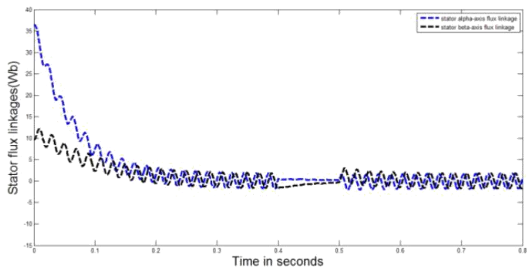
$$P_r = \frac{3}{2}(V_{\alpha r} i_{\alpha r} + V_{\beta r} i_{\beta r}) \qquad (23)$$

$$Q_s = \frac{3}{2}(V_{\beta s} i_{\alpha s} - V_{\alpha s} i_{\beta s}) \qquad (24)$$

$$Q_r = \frac{3}{2}(V_{\beta r} i_{\alpha r} - V_{\alpha r} i_{\beta r}) \qquad (25)$$

4. SIMULATION RESULTS

A simulation study was performed on a 2MW 690V DFIG with synchronous speed of 1500 rev/min, rated stator current is 1760A and other relevant parameters are specified in DFIG turbine parameter table. Based on alpha and beta modeling, stator flux linkages, rotor flux linkages, stator currents, rotor currents, speed of the rotor and Electromagnetic torque parameters are shown in Fig.2.(a) to Fig.2.(g).



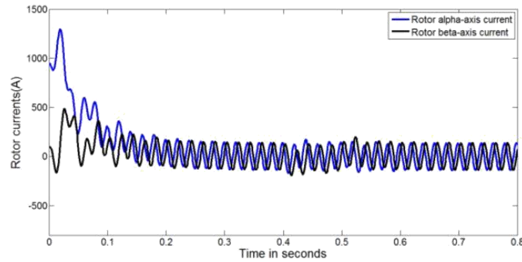
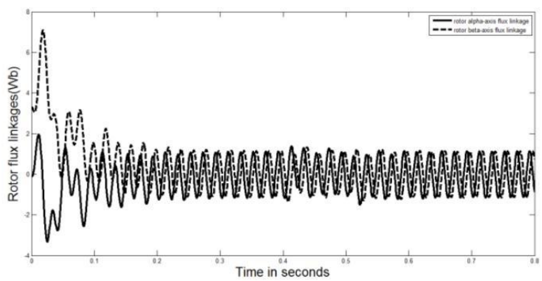


Fig.2(a) Stator flux linkages in alphabeta reference Fig.2.(e) Rotor currents in alphabeta reference



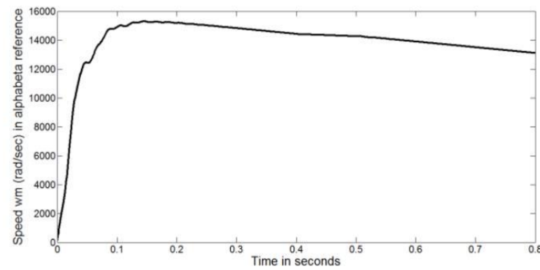
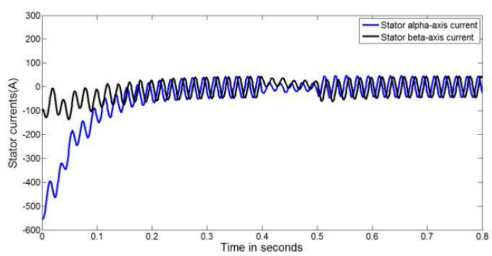


Fig.2.(f) Mechanical speed in alphabeta reference Fig.2.(c) Rotor flux linkages in alphabeta reference



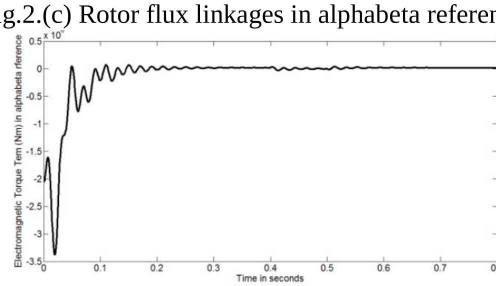
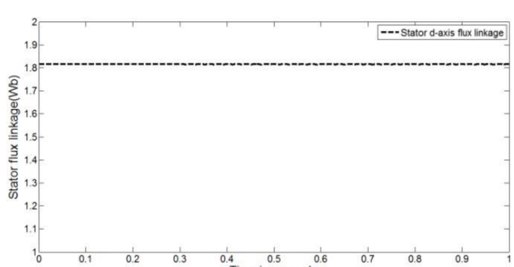


Fig.2.(d) Stator currents in alphabeta reference Fig.2.(g) Electromagnetic Torque in alphabeta reference

Based on d-q modeling, stator flux linkages, rotor flux linkages, stator currents, rotor currents, speed of the rotor and Electromagnetic torque parameters are shown in Fig.3.(a) to Fig.3.(j).



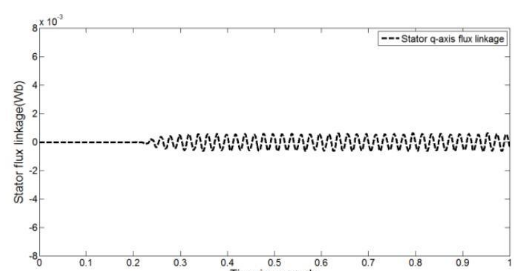
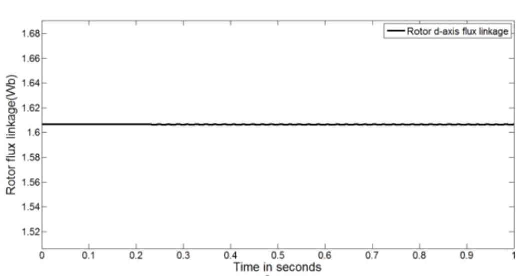


Fig. 3.(a) Stator d-axis flux linkage in d-q reference Fig. 3.(b). Stator q-axis flux linkage in d-q reference



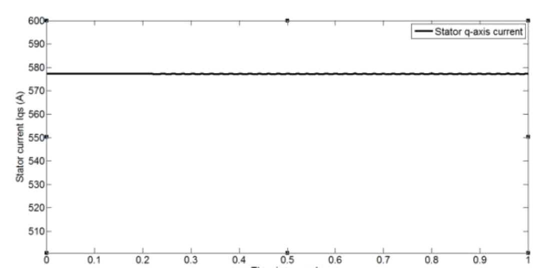
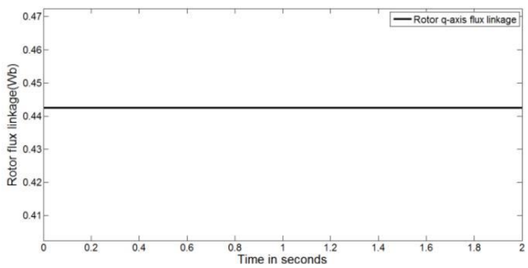


Fig. 3.(c) Rotor d-axis flux linkage in d-q reference Fig. 3.(d) Stator q-axis flux linkage in d-q reference



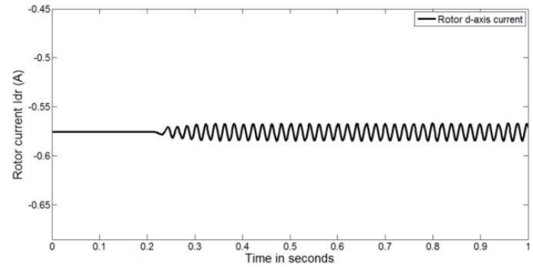
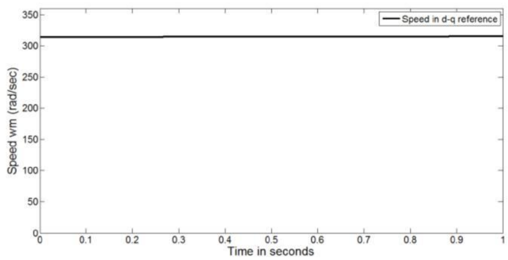


Fig. 3.(e) Rotor q-axis flux linkage in d-q reference Fig. 3.(f) Rotor d-axis flux linkage in d-q reference



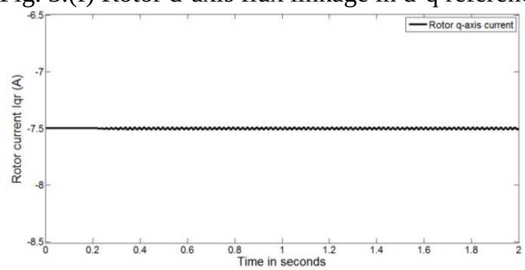
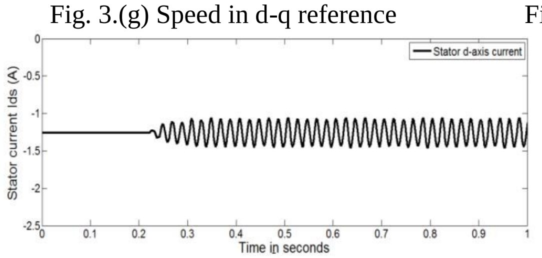


Fig. 3.(g) Speed in d-q reference Fig. 3.(h) Rotor q-axis flux linkage in d-q reference



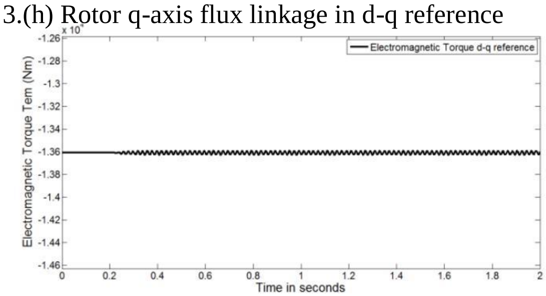
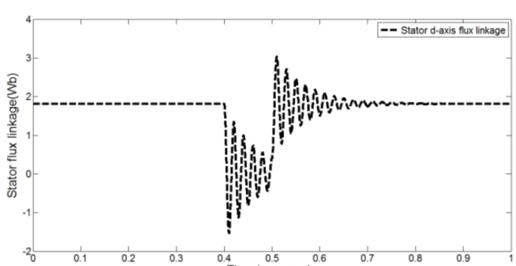


Fig. 3.(i) Stator d-axis current in d-q reference Fig.3.(j) Electromagnetic Torque in alphabeta reference

A disturbance is created with a duration of two seconds which is between 0.4 sec to 0.6 sec in d-q modeling of DFIG equipped with wind turbine is shown in Fig.4.(a) to Fig.4.(j).



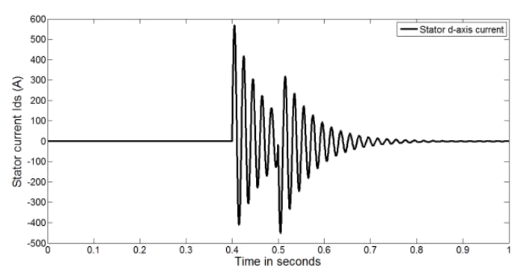
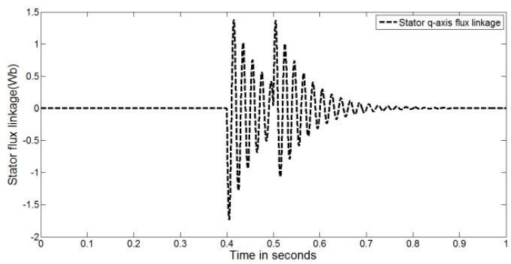


Fig. 4.(a) Stator d-axis flux linkage in d-q reference under fault Fig. 4.(f) Stator d-axis current in d-q reference under fault



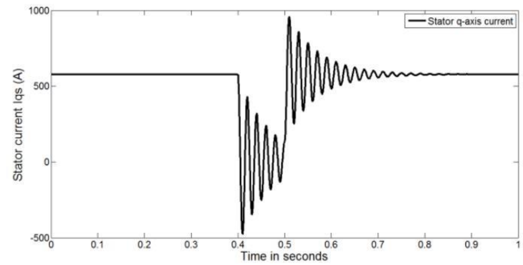
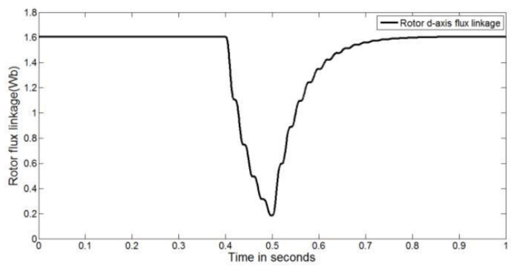


Fig. 4.(b) Stator d-axis flux linkage in d-q reference under fault Fig. 4.(g) Stator q-axis current in d-q reference under fault



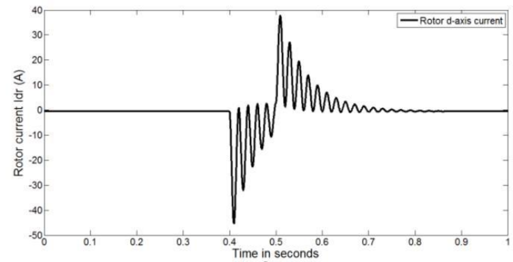
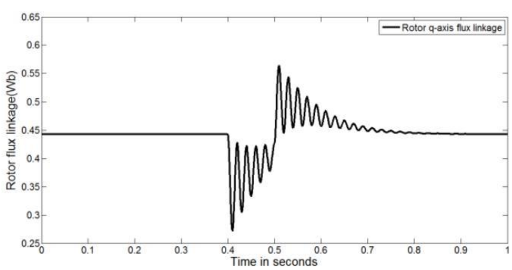


Fig. 4.(c) Rotor d-axis flux linkage in d-q reference under fault Fig. 4.(h) Rotor d-axis current in d-q reference under fault



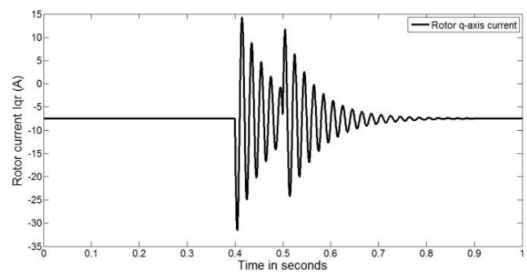
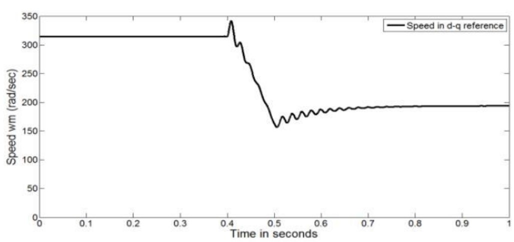


Fig. 4.(d) Rotor d-axis flux linkage in d-q reference under fault .

Fig. 4.(i) Rotor q-axis flux linkage in d-q reference under fault



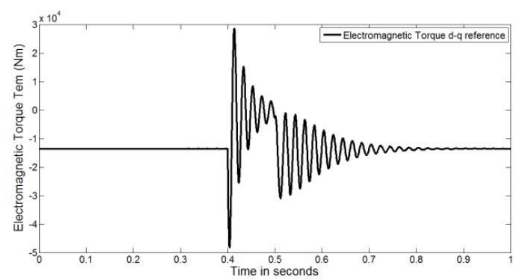


Fig. 4.(e) Mechanical speed in d-q reference under fault Fig. 4.(j) Stator d-axis flux linkage in d-q reference under fault

Table 1 DFIG Wind system Parameters

Parameter	Value	Units
Prated	2	MW
Rs	2.6	m□
Rr	2.9	m□
Ls	2.587	mH
Lr	2.587	mH
Lm	2.5	mH
Slip	-0.25	NA

5. CONCLUSION

Because of problems encountered in power sector needful and accurate modeling has to be done to give a remedy for power shortage. In order to get that simulation of DFIG based wind turbine has been done under fault condition and hence a dynamic model with full-order representation for the DFIG and its associated circuits has been analysed and developed.

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