Control Method of Doubly Fed Induction Generator at Fault Condition

M. Sindhuja[1], T. R. Jyothsna[2]
1Mtech Student, 2Professor
Department of Electrical Engineering, Andhra University, Visakhapatnam

Abstract-Doubly Fed Induction Generators (DFIG) are majorly used in wind energy power generation. When DFIG system is subjected to symmetrical faults the wind turbine is disconnected and causes severe loss. When the system is at fault condition it should be connected with the grid without disconnecting is low voltage ride through capability which can be achieved with crowbar protection. The crowbar is connected to rotor side of DFIG and when system is subjected to symmetrical fault condition the crowbar is activated and have control over the system. In this paper, the behavior of 2MW DFIG is studied under severe fault. Simulation blocks designed using MATLAB-Simulink software on a 2MW DFIG system.

***Keywords*:-** *Doubly Fed Induction Generator(DFIG).*

Nomenclature

ψ_s, ψ_r : Stator flux and rotor flux
$V_s,\ V'_r$:Supplied stator voltage & rotor voltage
T_{em} : Electromagnetic torque
L_s, L_r : Stator inductance and rotor inductance

I. INTRODUCTION

Use of conventional energy sources increasing carbon dioxide levels in the nature, the renewable energy systems, especially wind energy generation, attracted many in power generation in recent years. Wind energy power generation with doubly fed induction generator based wind turbine has been extensively used due to some advantages such as inverter cost is very less, torque control and efficiency. This paper deals with the 2MW DFIG using crowbar protection when subjected to symmetrical voltage dips by MATLAB-Simulink software.

II. DFIG MODEL

The DFIG model equations using stator voltage, rotor voltage, stator flux and rotor flux in stator reference frame.

$$\vec{v}_s = R_s\vec{\iota}_s + \frac{d\vec{\Psi}_s}{dt} \quad (1)$$

$$\vec{v}_r = R_r\vec{\iota}_r + \frac{d\vec{\Psi}_r}{dt} - j\omega_m\vec{\Psi}_r \quad (2)$$

$$\vec{\Psi}_s = L_s\vec{\iota}_s + L_h\vec{\iota}_r \quad (3)$$

$$\vec{\Psi}_r = L_r\vec{\iota}_r + L_h\vec{\iota}_s \quad (4)$$

The electromagnetic torque equation:

$$T_{em} = \frac{3}{2}pIm\{\vec{\Psi}_s^*.\vec{\iota}_s\} \quad (5)$$

Dynamic Modeling of DFIM in dq reference frame:

Voltage equations of stator and rotor:

$$v_{ds} = R_s i_{ds} + \frac{d\psi_{ds}}{dt} - \omega_s\psi_{qs} \quad (6)$$

$$v_{qs} = R_s i_{qs} + \frac{d\psi_{qs}}{dt} - \omega_s\psi_{ds} \quad (7)$$

$$v_{dr} = R_r i_{dr} + \frac{d\psi_{dr}}{dt} - \omega_r\psi_{qr} \quad (8)$$

$$v_{qr} = R_r i_{qr} + \frac{d\psi_{qr}}{dt} - \omega_r\psi_{dr} \quad (9)$$

DFIM model in dq reference frame, is represented in Figure 1.

Power equations:

$$P_s = \frac{3}{2}(v_{ds}i_{ds} + v_{qs}i_{qs}) \quad (10)$$

$$P_r = \frac{3}{2}(v_{dr}i_{dr} + v_{qr}i_{qr}) \quad (11)$$

$$Q_s = \frac{3}{2}(v_{qs}i_{ds} - v_{ds}i_{qs}) \quad (12)$$

$$Q_r = \frac{3}{2}(v_{qr}i_{dr} - v_{dr}i_{qr}) \quad (13)$$

Torque equation:

$$T_{em} = \frac{3}{2}p\frac{L_m}{L_s}Im\{\vec{\psi}_s^*.\vec{\iota}_r\} = \frac{3}{2}p\frac{L_m}{L_s}(\psi_{qs}i_{dr} - \psi_{ds}i_{qr}) \quad (14)$$

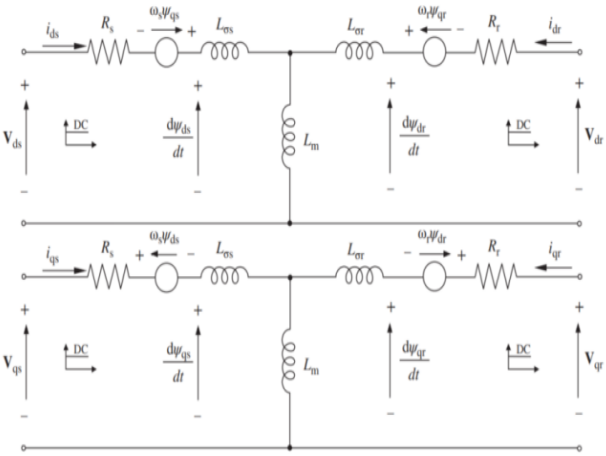


Fig.1: DFIM model in dq reference frame

Dynamic Modeling of Grid Side System in dq reference frame:

Grid voltage, currents and converter voltage equations:

$$\vec{v}_f{}^s = v_{\alpha f} + jv_{\beta f} \quad (13)$$

$$\vec{v}_g{}^s = v_{\alpha g} + jv_{\beta g} \quad (14)$$

$$\vec{\iota}_g{}^s = i_{\alpha g} + ji_{\beta g} \quad (15)$$

$$v_{df} = R_f i_{dg} + L_f\frac{di_{dg}}{dt} + v_{dg} - \omega_a L_f i_{qg} \quad (16)$$

$$v_{qf} = R_f i_{qg} + L_f \frac{di_{qg}}{dt} + v_{qg} + \omega_a L_f i_{dg} \quad (17)$$

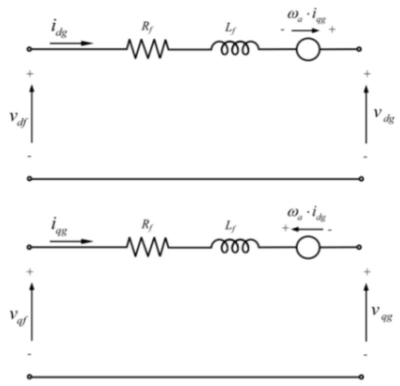


Fig 2 : Grid side system in dq reference frame

III. DFIG CONTROL

In figure 3, the entire system of DFIG construction is shown. In figure 4 RSC control. In figure 5 GSC control are shown.

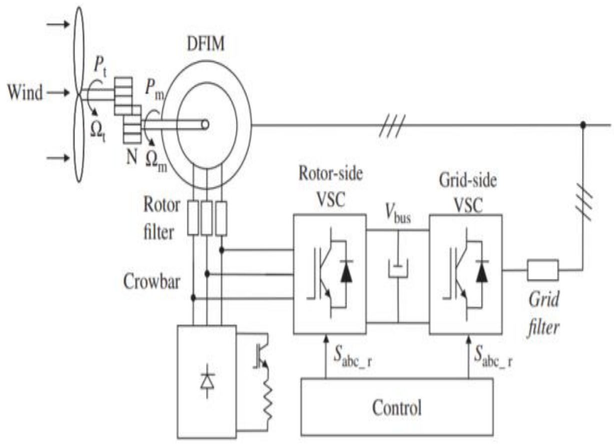


Fig 3:DFIG.

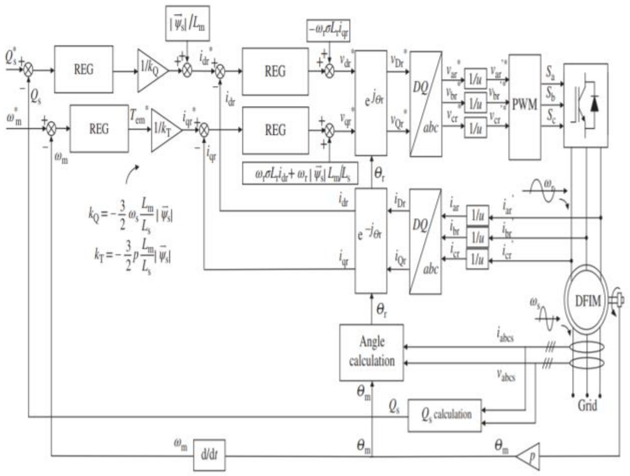


Fig 4: Rotor side converter control.

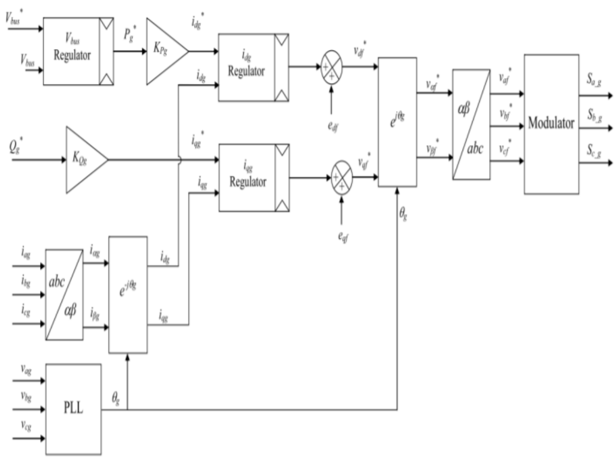


Fig 5: Grid side converter control.

Crowbar protection:

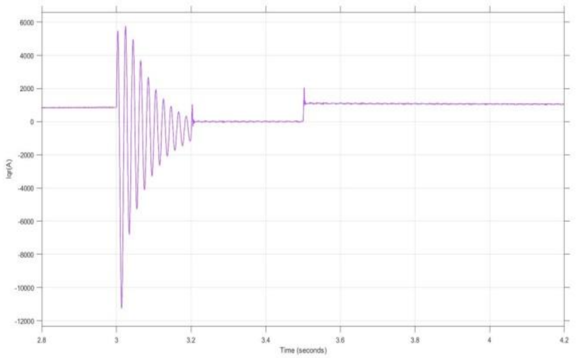
Crowbar protection is used at the rotor side of doubly fed Induction Generator. When the system is subjected to symmetrical voltage dips the crowbar protection is activated and when voltage is recovered the crowbar protection is deactivated.

Table I:System Data

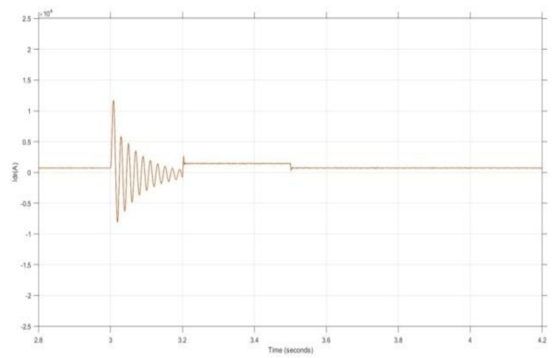
Parameter	Value
n_s	1500 rev/min
P_s	2 MW
V_s	690 Vrms
I_s	1760 Arms
T_{em}	12.7 kNm
Connection of stator	Star
p	2
V_r	2070 Vrms
Connection of rotor	Star
u	0.34
R_s	2.6 mΩ
$L_{\sigma s}$	87 µH
L_m	2.5mH
R'_r	26.1mΩ
$L'_{\sigma r}$	783µH
R_r	2.9mΩ
$L_{\sigma r}$	87µH

IV. SIMULATION RESULTS

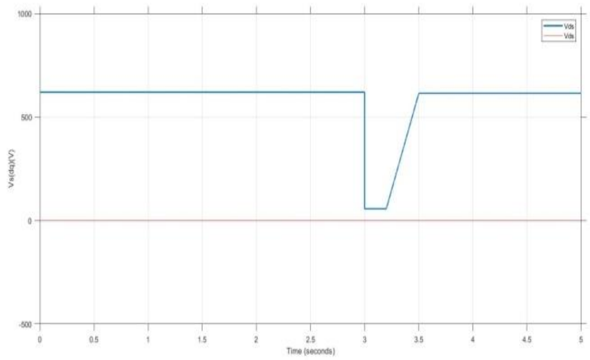
Simulation performed for 2MW DFIG system. The simulated disturbance is a three-phase 90% symmetrical voltage dip occurs at the 3seconds for a duration of 200 milliseconds. At the time of dip, the crowbar is activated by disconnecting rotor side converter control as high currents flow through rotor which can damage the converter. At 3seconds, high rotor currents and high torques appears in the system at same time crowbar protection is activated. After 3.2 seconds, the crowbar is disconnected as the flux has decayed and at the 3.2 seconds the rotor side converter is activated, from 3.2 to 3.5 seconds the voltage of the grid is recovered progressively. During the grid voltage recovery as demanded by grid codes the reactive power compensation is provided for safe and secure operation of the system and injects d rotor current in RSC and q grid current in GSC. After 3.5 seconds the system is recovered, fault is cleared and attains normal operation.



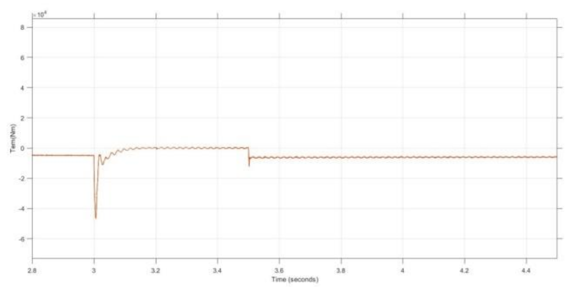
(a)



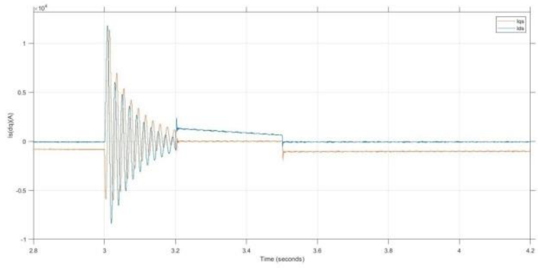
(b)



(c)



(d)



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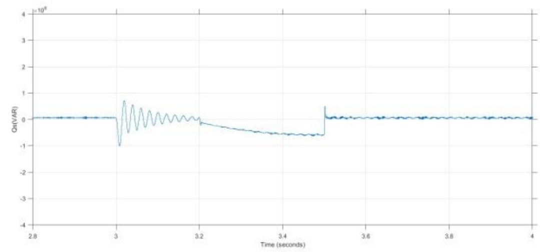

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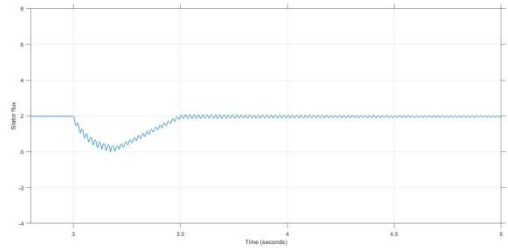
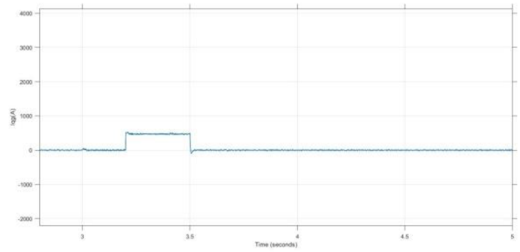


(g)



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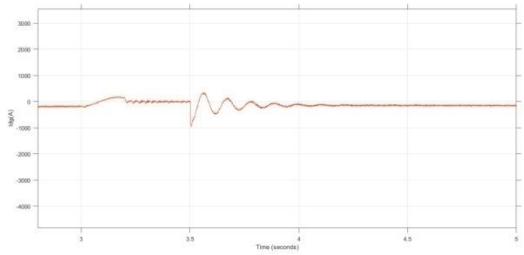
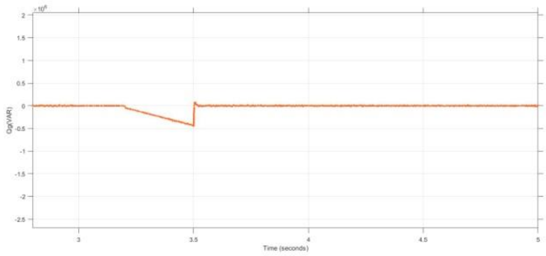


(i)



(j)

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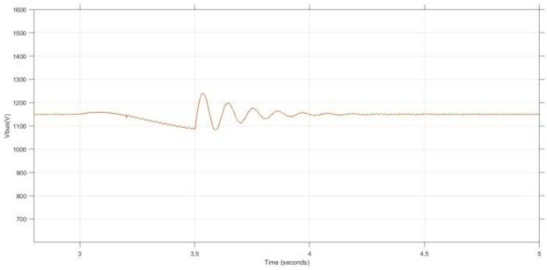
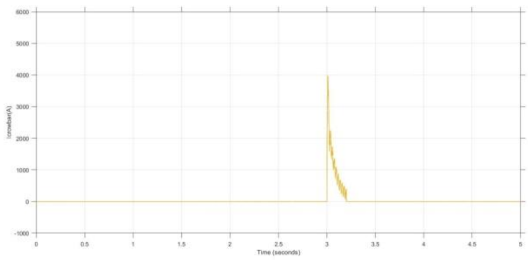


(k)



(l)

Fig 6: Simulation results of 2MW DFIG under symmetrical voltage dips using crowbar protection

(a)q axis rotor current Iqr(A) (b)d axis rotor currentIdr(A) (c)statorvoltageVs(V) (d)electro magnetic torqueTem(Nm) (e)stator currentsIs(A) (f)reactivepowerQs(VAR) (g)stator flux (h)q axis grid current Iqg(A) (i)d axis grid current Idg(A) (j)grid reactive power Qg(VAR) (k)busvoltageVbus(V) (l)Icrowbar(A)

V. CONCLUSION

In this paper, the behavior of 2MW DFIG at severe symmetrical voltage dip in presence of crowbar protection is analyzed. Simulation of 2MW DFIG based wind turbines is investigated. When the crowbar has to be activated is a critical parameter of the operation of crowbar. When the crowbar protection is used, rotor current is decreased. At the time when the voltage is recovered progressively and regulators can control the machine, the crowbar is disconnected and the RSC control is activated again. According to the requirements of grid codes, reactive power compensation is provided by injecting d rotor current at rotor side converter and q grid current at grid side converter during the dip recovery these results are plotted. After fault clearance the system attains normal operation.

REFERENCES

[1]. Min Min Kyaw, V.K.Ramachandramurthy."Fault Ride Through and Voltage Regulation for Grid Connected Wind Turbine",Science Direct , Rnewable Energy 36(2011)206-215.

[2]. L.Shi, N.Chen and Q.Lu, "Dynamic Characteristic Analysis of Doubly Fed Induction Generator Low Voltage Ride-Through",Science Direct, Energy Procedia16(2012)1526-1534.

[3]. Christian Wessels, Fabian Gebhardt and Friedrich W.Fuchs, "Dynamic Voltage Restorer to allow LVRT for a DFIG Wind Turbine",IEEE International Symposium onIndustrial Electronics(ISIE),2010.

[4]. J.Lopez, P.Sanchis, X.Roboam, L.Marroyo "Dynamic Behaviour of Doubly Fed Induction Generator During Three Phase Voltage Dips ", IEEE Transaction on EnergyConversion, Vol.22, no.3, 2007,pp.709-717.

[5]. M.Garcia-Gracia, M.P.Comech, J.Sallan,and A.Llombart,"Modelling Wind Farms For Grid Disturbance Studies",Science Direct, Renewable Energy,33,2008,pp.2109-2121.