Simulation of a Doubly Fed Induction Generator based Wind Energy Conversion System using MATLAB

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Abstract - *Doubly fed induction generators are wide employed in wind energy conversion system because of its low device price, simplicity, and improved potency etc. The doubly fed induction generator stator coil windings are directly connected to the grid whereas the rotor windings are connected to the grid via power electronic converters. The field oriented control is often used for doubly fed induction generator. The modelling of doubly fed induction machine is also presented and different output waveforms are analyzed.*

***Key Words*: Doubly fed induction generator, wind turbine, field oriented control, wind energy conversion system, power electronic converters**

1. INTRODUCTION

Nowadays the wind energy plays a vital within the world as a result of its environmental friendliness and availability. The wind turbines utilized in wind energy conversion system (WECS) are mainly constant speed and variable speed. Among them variable speed turbine is more energy efficient since the wind speed is variable in nature. Squirrel cage induction generator (SCIG), doubly fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) are the 3 sorts of generator used for wind energy conversion system, among this DFIG is most typically used for WECS as a result of its advantages like improved efficiency, active and reactive power management, reduced losses, reduced convertor price and ability of power factor correction..

In DFIG primarily based wind energy conversion system, the stator windings of DFIG is directly connected to the grid whereas the rotor windings are connected to the grid via power electronic devices like rotor and grid side converters. DC link capacitor connected between rotor and grid side device act as DC voltage supply. The converters [1] employed in DFIG primarily based WECS need only a fraction of the generated output power so the converters are designed to transfer 30% of the total power. The active and reactive power from stator to grid of the turbine is controlled by rotor side converter [2]-[4]. The grid side converters controls the dc link voltage and permits the device to generate or absorb reactive power [5]-[6]. In DFIG the stator and rotor can offer power so it's referred to as doubly fed.

Field oriented control (FOC) or vector control is usually utilized in doubly fed induction generator controls because of its ability of controlling the motor speed more efficiently.

Field oriented control conjointly provides the flexibility of controlling the active and reactive power of the generator one by one. Currently, there are commonly two sorts of field oriented control in DFIGs, they are stator voltage and stator flux oriented control, respectively. The stator flux oriented control is wide utilized in the DFIG control designs [7] within which the q-axis current element is employed for active power management and also the d-axis element is employed for reactive power management. Whereas for the stator voltage oriented control, the case is on the contrary, the d-axis element is employed for active power management and also the q-axis current element is employed for reactive power management.

2. DOUBLY FED INDUCTION GENERATOR

The doubly fed induction generator basic block diagram is shown in Fig. 1. In this the stator windings is directly connected to the grid whereas the rotor windings are connected to the grid via power electronics converters such as rotor side and grid side converter.
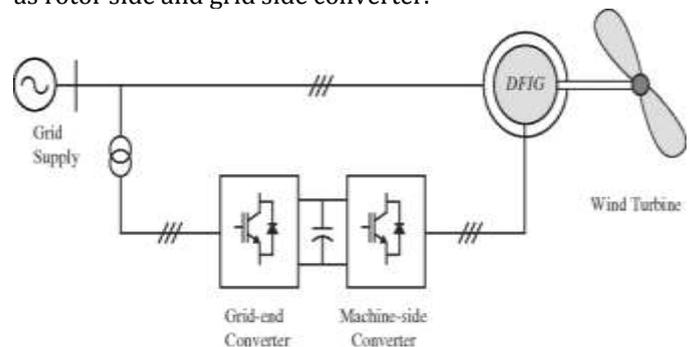
Fig -1: Doubly Fed Induction Generator

Mathematical modelling equations of DFIG is given below, Stator and rotor voltage equations are,

$$V_{ds} = R_s i_{ds} + \frac{1}{\omega_b}\frac{d}{dt}F_{ds} - \frac{\omega_e}{\omega_b}F_{qs} \qquad (1)$$

$$V_{qs} = R_s i_{qs} + \frac{1}{\omega_b}\frac{d}{dt}F_{qs} + \frac{\omega_e}{\omega_b}F_{ds} \qquad (2)$$

$$V_{dr} = R_r i_{dr} + \frac{1}{\omega_b}\frac{d}{dt}F_{qr} + \frac{(\omega_e - \omega_r)}{\omega_r}F_{dr} \qquad (3)$$

$$V_{qr} = R_r i_{qr} + \frac{1}{\omega_b}\frac{d}{dt}F_{dr} - \frac{(\omega_e - \omega_r)}{\omega_r}F_{qr} \qquad (4)$$

Where Vds, Vqs, Vdr and Vqr are the stator and rotor d axis voltages and q axis voltages respectively. Rs and Rr are stator and rotor resistance respectively.

ωe is the angular speed and ωr is the rotor speed. ids, iqs, idr, and iqr are the stator and rotor d axis currents and q axis currents respectively. Fds, Fqs, Fdr and Fqr are the flux linkages.

Flux linkage expressions are,

$$\frac{d}{dt}F_{qs} = \omega_b[V_{qs} - \frac{\omega_e}{\omega_r}F_{ds} + \frac{R_s}{X_{ls}}(F_{mq} - F_{qr})] \qquad (5)$$

$$\frac{d}{dt}F_{ds} = \omega_b[V_{ds} - \frac{\omega_e}{\omega_r}F_{ds} + \frac{R_s}{X_{ls}}(F_{md} - F_{ds})] \qquad (6)$$

$$\frac{d}{dt}F_{dr} = \omega_b[V_{qr} - \frac{\omega_e - \omega_r}{\omega_r}F_{dr} + \frac{R_r}{X_{lr}}(F_{mq} - F_{qr})] \qquad (7)$$

$$\frac{d}{dt}F_{dr} = \omega_b[V_{dr} - \frac{\omega_e - \omega_r}{\omega_r}F_{qr} + \frac{R_r}{X_{lr}}(F_{md} - F_{dr})] \qquad (8)$$

Where Fmd and Fmq are the mutual flux linkages of d axis and q axis respectively.

Torque equation,

$$T_e = \frac{3}{2}\frac{P}{2}\frac{1}{\omega_b}(F_{ds}i_{qs} - F_{qs}i_{ds}) \qquad (9)$$
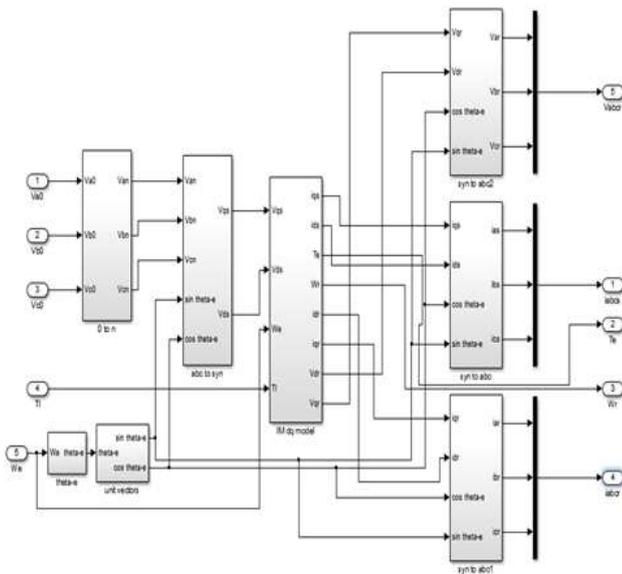
Fig -2: MATLAB model of DFIG
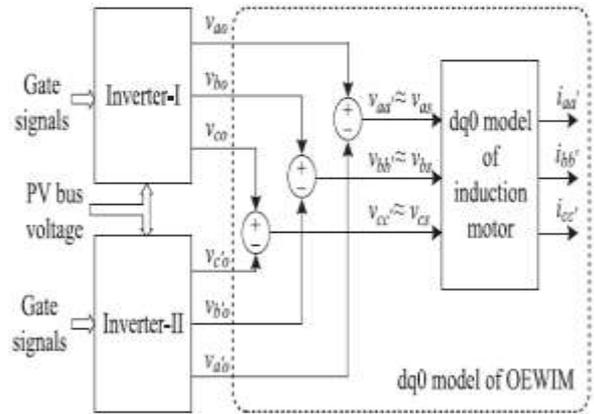
Fig -3: dq model of OEWIM

3. PROPOSED SYSTEM

3.1 Floating Capacitor Bridge inverter

The topology by using floating capacitor dual inverter has been analyzed for various applications [8].The capacitor floats with regard to the earth's potential that's neither of the two terminals are grounded. The capacitor are often used as a Nursing energy storage component to make a lower or higher voltage power supply. They often offer reactive power to a machine and can be used for compensating any voltage drop.
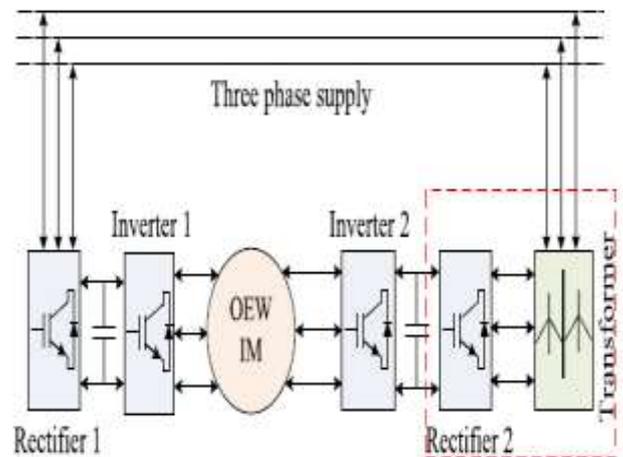
Fig -4: Conventional OEWIM topology

The proposed topology is to manage the voltage across the floating capacitor by implementing correct switching states thereby reducing the necessity of isolation transformer as shown in fig 4. The figure shows the traditional open end winding induction motor. One end of the machine is connected to a transformer to realize the desired output that will increase the weight, cost etc. This disadvantage can be overcome by using the proposed scheme that replaces the transformer with a floating capacitor bridge.
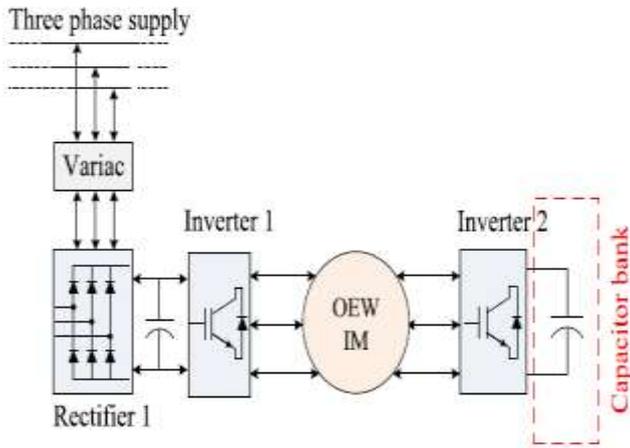
Fig -5: Block diagram of proposed topology

The figure shows an OEWIM and dual inverters with only a single dc source at the primary side and the second converter is connected to a floating capacitor bank.

3.2 Modulation Strategy

The modulation strategy used to control the voltage across the floating capacitor is by space vector pulse width modulation technique (SVPWM). The space vector pulse width modulation is a very advanced PWM methodology that is best appropriately used for three phase inverters. This strategy switches each of the inverters equally to get the specified output. This strategy has special switching sequences and can produce the output with less harmonic distortion and also provide additional economical use of supply voltage than the pulse width modulation techniques. The main objectives of the modulation scheme embrace wide linear modulation range, less switching losses and harmonic distortion, easy implementation and fewer process calculations.

3.3 Operating principle

The floating capacitor bridge can be charged and discharged by considering the proper switching states. The different switching combinations obtained from the space vector of dual inverters, there will be discharging, charging and neutral conditions for the floating capacitor.
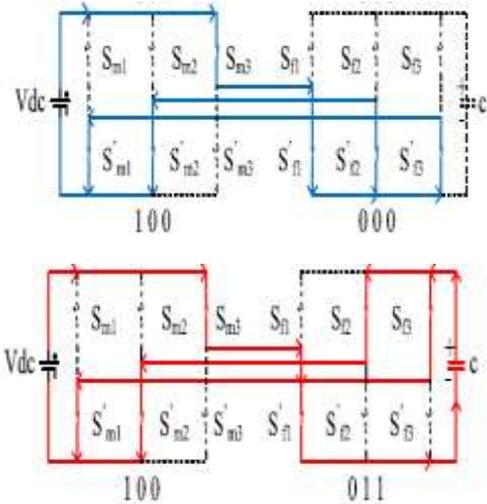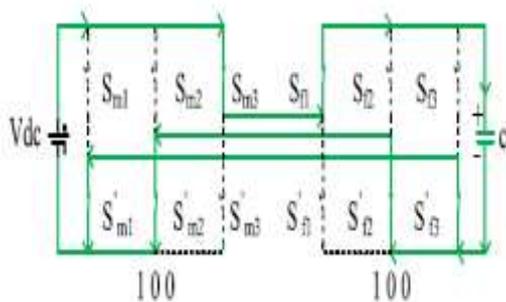
Fig -6: Modes of Operation

Consider an example of state (74) where 7 (1 1 1) represents the top three switches and 4 (0 1 1) represents the switching states of the top three switches of floating capacitor. From the figure the first mode shows the charging of capacitor, where the current flows from positive to negative terminal of the floating capacitor. The second mode are the zero states, therefore no impact on floating capacitor's voltage. The third mode shows that current flows from negative to positive terminal which results in the discharging of capacitor.

4. SIMULATION RESULTS

The following graphs shows the simulation results of doubly fed induction generator modelling in MATLAB. Fig 7 shows the input voltage waveform of doubly fed induction generator.
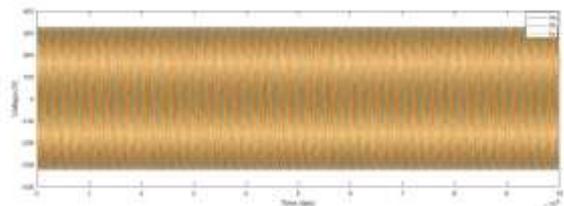
Fig -7: Waveform of input voltage
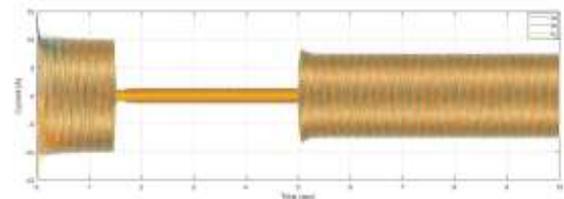
Fig -8: Stator Current of DFIG
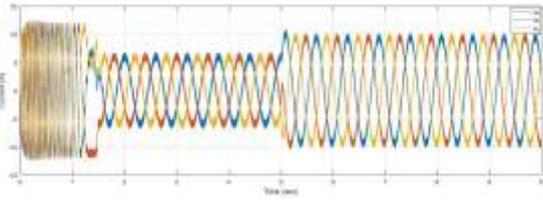
Fig -9: Rotor Current of DFIG
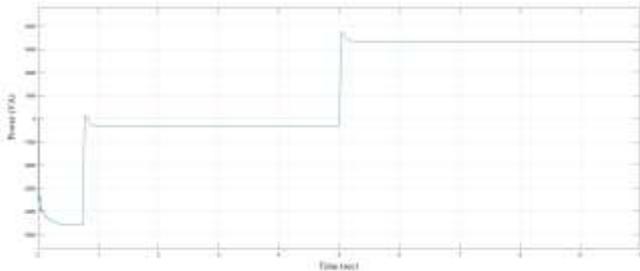
Fig -10: Output Power of DFIG

5. CONCLUSION

Induction machine with stator end windings are analyzed with twin inverters connected to the machine. The floating capacitor connected at one end of the device are often used atone for the voltage drop. The floating dc link voltage value are kept constant by charging and discharging of the floating bridge capacitor by correct switching combinations. The space vector modulation will avoid the unwanted voltage levels and might improve the wave shape quality of the floating bridge topology.

APPENDIX A: DFIG PARAMETERS

Rated voltage = 400 V

Rated power = 4 KW

Rated speed = 1800 rpm

No. of poles = 4

Stator winding resistance, R_s = 1.405 Ω

Rotor resistance, R_r = 1.395 Ω

Stator leakage inductance, L_{ls} = 0.005839 H

Rotor leakage inductance, L_{lr} = 0.005839 H

Mutual Inductance, L_m = 0.1722

Moment of inertia, J = 0.131 Kg m^2

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