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Performance Analysis of Wind Energy System Coupled with Brushless Doubly Fed Induction Generator and Matrix Convertor

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Abstract - This Paper represents Performance analysis of Brushless Doubly Fed Induction Generator Coupled with matrix convertor in wind energy system. Some of important research and developments are overviewed for this research. Because of the advantages of the BDFIG over other generators it is being used for most of the wind applications. Various researches have been done in modeling and simulation in field of DFIG. The performance of the brushless doubly-fed machine (BDFM) is analyzed using a per- phase equivalent circuit. An expression for the rating of machine as a function of magnetic and electric loadings is developed, and the rating is compared to those of the doubly-fed induction machine and cascaded induction machines. As the magnetic field in a BDFM is complex, the magnetic loading is considered in detail and a new generalized loading is derived. This paper summaries the researches in the area of study of DFIG, steady state and transient analysis, its modeling, simulation, reactive power control strategies and performance analysis of BDFIG coupled with wind turbine. The response of BDFIG wind turbine system to grid disturbances, which is simulated and verified experimentally.

Index Terms — BDFIG, Wind Turbine, Matrix Converter, Low Pass Filter, PI Controller, Maximum power point tracking.

1. Introduction

Wind power, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effects on the environment are generally less problematic and effective than those from other power sources. As record of 2011, Denmark is generating more than a quarter of its electricity from wind and 83 countries around the world are using wind power to supply the electricity grid. In record of 2010 wind energy production was over 2.5% of total worldwide electricity usage, and growing rapidly at more than 25% per annum.

The Indian wind energy sector has an installed capacity of 18.551 GW (up to 31.02.2013) [A]. In terms of wind power installed capacity, India is ranked 5th in the World [B]. Today India is a major player in the global wind energy market. The potential is far from exhausted. Indian Wind Energy Association has estimated that with the current level of technology, the 'on-shore' potential for utilization of wind energy for electricity generation is of the order of 102 GW [C]. According to the Centre for Wind Energy Technology, Government of India- Growing concern for the environmental Degradation has led to the world's interest in renewable energy resources. Wind is commercially and operationally the most viable renewable energy resource and accordingly, emerging as one of the largest source in terms of the renewable energy sector.

The Doubly Fed Induction Generator (DFIG) is widely used in wind energy power generation. To connect the turbine or turbines to the mains, specifications listed in the national Grid Code must be respected. Voltage and power characteristics and fault ride through are handled by the control system of the turbine. To analyses a DFIG system a simulation model is useful.

Doubly-fed machines are attractive as variable speed drives or generators because the associated inverter only needs a fractional rating compared to that of the machine. Potential applications include generation from wind power [3] and integrated drives [4]. This paper is concerned with one type of doubly-fed machine, the brushless doubly-fed machine (BDFM). The BDFM has two stator windings, each producing an air gap field of a different pole number, chosen to avoid transformer coupling between the stator windings. The rotor is specially designed to couple to both air gap fields. A comparison of the BDFM with other types of doubly-fed systems has been given by Hopfensperger and Atkinson [5]. Recent work on the BDFM includes the generalized analysis published by Williamson et al. [6], studies of power flow through the machine [7,8] and the equivalent circuit approach proposed by Roberts et al. [9]. However, there remains a need to consider the operation of the machine from the perspective of terminal quantities. In this paper we show how the use of the equivalent circuit for the machine leads to an understanding of operating conditions and hence how the rating of a BDFM can be established. [6,10].

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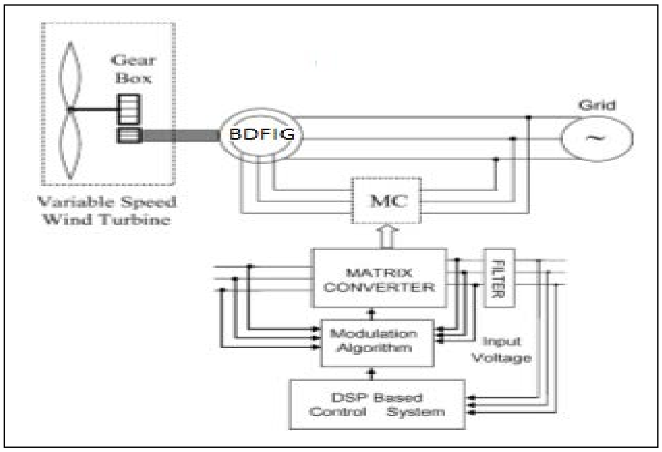
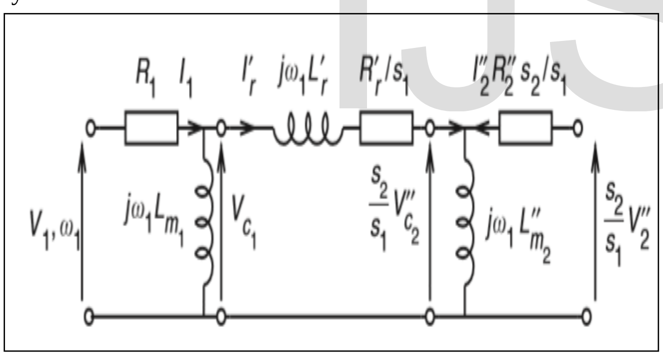
2. Bdfig System



A per-phase equivalent circuit for the BDFM based on two induction machines with connected rotors is given [8]. As it was not possible to determine all the parameters explicitly from measurements, an electrically equivalent circuit for which all parameters could be found was proposed. This circuit, shown in Fig., is used in this paper; the machine is taken to be three-phase. Parameters are shown referred to the power winding and iron losses are neglected. The circuit is valid for operation, including the synchronous mode.



Referred per-phase equivalent circuit

In this form of the equivalent circuit, the stator leakage inductances are not shown explicitly and the values of the magnetizing inductances and turns ratios for the two windings therefore have slightly modifide values. The referred and actual stator 2 supply voltages are related.

The stator equation is presented below:

$$\underline{u}_s = R_s \underline{i}_s + \frac{d\underline{\psi}_s}{dt} + j\omega_e \underline{\psi}_s$$

Where

us - the stator voltage space vector,

is - the stator current space vector,

Rs - The stator resistance,

ψ s – stator flux, ωe - the reference frame speed (arbitrary),

j – Complex operator.

The stator voltage may be expressed as a sum of the stator d and q voltage components:

$$\underline{u}_s = u_{sd} + ju_{sq}$$

is, ir the stator and rotor current space vectors are also expressed in d and q components:

$$\underline{i}_s = i_{sd} + ji_{sq} \qquad \underline{i}_r = i_{rd} + ji_{rq}$$

Ψ s, Ψ r the stator and rotor flux space vectors,

$$\underline{\psi}_s = L_s \underline{i}_s + L_m \underline{i}_r \qquad \underline{\psi}_r = L_r \underline{i}_r + L_m \underline{i}_s$$

ur is the rotor voltage space vector equation is written for the rotor circuit.

$$\underline{u}_r = R'_r \underline{i}_r + \frac{d\underline{\psi}_r}{dt} + j(\omega_e - \omega_r)\underline{\psi}_r$$

R'r is the rotor equivalent resistor and ωr is the rotor speed,

$$\underline{u}_r = u_{rd} + ju_{rq}$$

$$\underline{\psi}_s = \psi_{sd} + j\psi_{sq} \qquad \underline{\psi}_r = \psi_{rd} + j\psi_{rq}$$

Where

R'r is the rotor equivalent resistor and ωr is the rotor speed,

$$L_s = L_m + L_{s\sigma} \qquad L_r = L_m + L_{r\sigma}$$

Where sσL is the stator leakage inductance and

rσ L is the rotor leakage inductance

The mechanical equation comprising the rotor inertia J, load torque TL, electromagnetic torque Te and the rotor speed ωr is written as

$$J\frac{d\omega_r}{dt} = T_e - T_L$$

The electromagnetic torque is a function of the machine pole pairs (p) and stator currents and fluxes

$$T_e = \frac{3}{2}p(\psi_{sd} i_{sq} - \psi_{sq} i_{sd})$$

3. MC Topology

The back-to-back converters are replaced by an MC. A space vector modulation (SVM) algorithm [11] is used to control the MC, regulating the rotor torque and magnetizing currents. In the MC input side, a second-order LC power filter is used to improve the current waveform and reduce the input voltage distortion [12]. the interaction between the MC and input power filter may produce resonances and even instability in the system. This paper analyzes the stability of the system using a small signal model of the BDFIG and MC. It is demonstrated in this paper that the dynamic performance improves, when the BDFIG stator voltage is used by the SVM algorithm to generate the MC switching pattern. The stability

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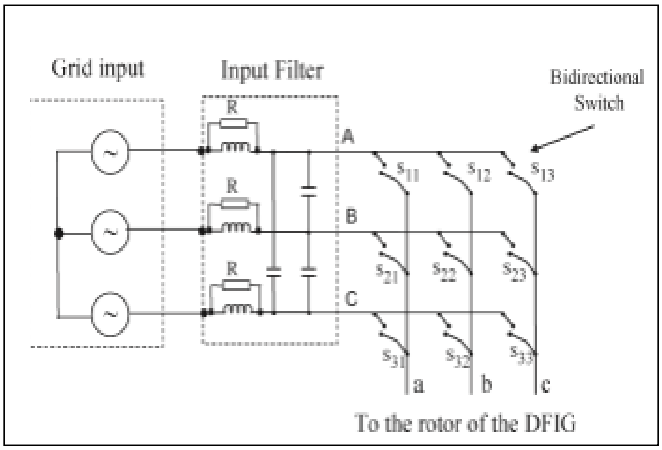
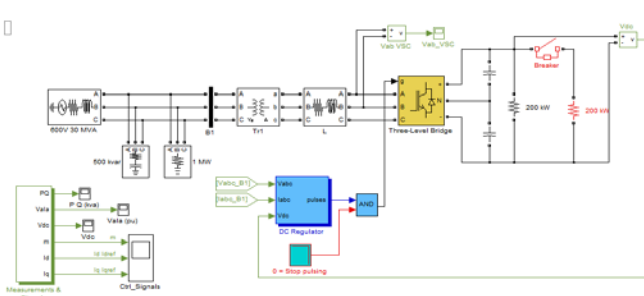
of this control arrangement is compared with that of a conventionally controlled MC, where the MC input voltage is input to the SVM algorithm. The dynamic performance of two control arrangements is assessed and the stability of the proposed control system is analyzed.experimental results and an appraisal of the proposed control system is presented in the Conclusion.



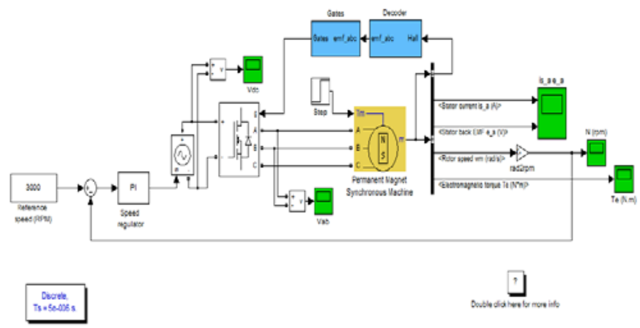
The MC topology used, A second-order L–C filter is used at the input to improve the quality of the currents [11]. The filter capacitors also provide the essential decoupling to minimize the commutation inductance between phases. Usually, a resistor in parallel with the filter inductance improves the damping of the system. In most reported MC applications, the voltage used in the modulation algorithm is the capacitor input voltage [11], [12].

4. Result Analysis Part

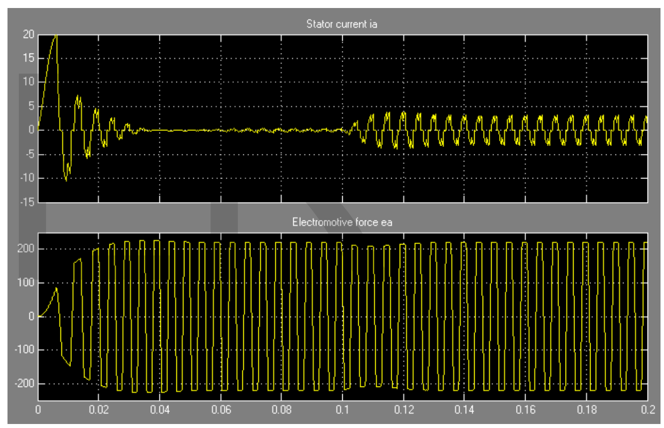
We are work on BDFIG wind power generation. We design in this model three basic section one is wind power generation, second is DFIG block and last is control unit. Control unit is basic fundamental which take all control part like angle of turbine section and turbine speed. One is converter unit in which we used Matrix converter in place of back to back convertor. Simulation block for convertor section are shown blow.



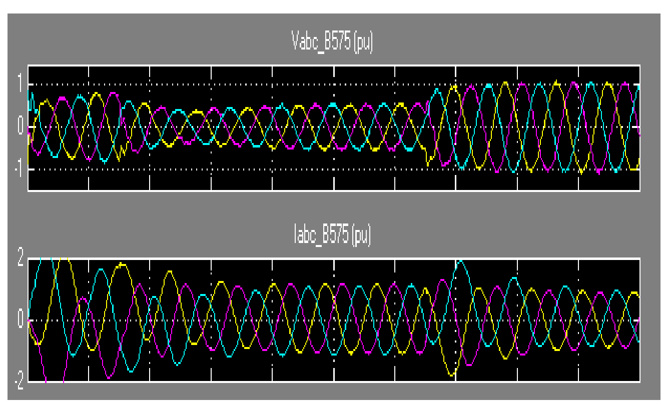
A brushless wound rotor induction motor is used in this research. there are so many benefits of BDFIG over DFIG system. In wind turbine block wind energy id taken as 15m/s and torque is given by turbine after simulation process is 1.248 pu. As well as speed is changed torque will change automatically. Simulation block diagram of motor are show below

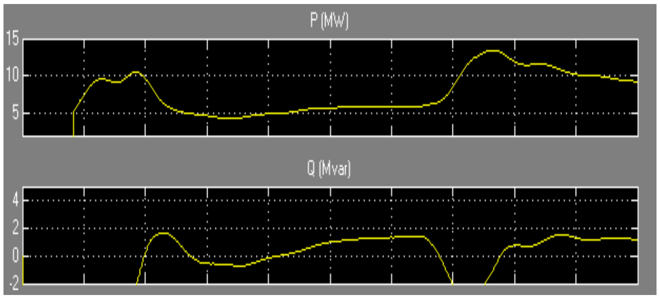


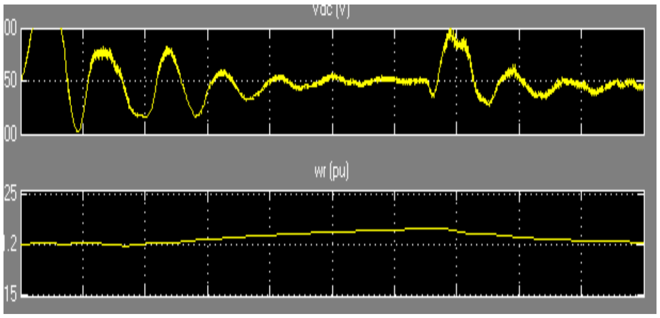
This motor outputs stator current, electromotive force and rotor speed are moved to next section that is control unit. These outputs are shown blow



In control unit block, we are controlling harmonics, vibration, rotor side control, grid side control. Our BDFIG block including convertor and control blocks that mean ore propose model outputs are active and reactive power at wind speed are shown after simulation process.







5. Conclusion

The engineering and design aspects of a BDFIG working with consisting of Matrix convertor converter. A BDFIG system with a matrix converter at the rotor end is simulated using PI controllers. The system performance analysis is done under steady state and for a sudden change in grid voltage. The generated stator voltages and currents, active power supplied to grid, VAR requirement for the BDFIG are observed and it is concluded that with the implemented vector control strategy, the brushless doubly fed induction generator system under simulation study is suitable under sudden change in grid voltage. Simulation results prove the feasibility and validity of the proposed model, theoretical analysis and performance of the proposed control scheme. The future work is in progress, including the study of experiment and the exploration of other application possibilities.

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[B]http://cwet.res.in/web/html/information_wcw.html

[C] http://www.inwea.org/