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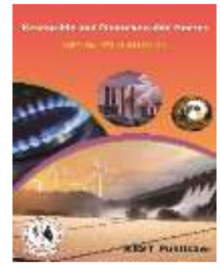

Performance Analysis of D fig-Based Wind Power Conversion with Grid Power Leveling for Geduced Gusts

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Abstract: *A new control strategy for grid connected doubly fed induction generator(DFIG)-based wind energy conversion system(WECS) is presented in this paper. Control strategies for grid side and rotor side converters placed in rotor circuit of DFIG are presented along with the mathematical modelling of the employed configuration of WECS. These topology includes a battery energy storage system(BESS) to reduce the power fluctuations on the grid due to varying nature and unpredictability of wind. Existing control strategies like the maximum power point extraction of wind turbine, unity power factor operation of the DFIG are also addressed along with proposed strategy of grid power leveling.An analysis is made in terms of active power sharing between the DFIG and the grid taking into account the power stored or discharged by the BESS, depending on the available wind energy. The proposed strategy is developed by using Mat Lab/Simulink and is used to predict the behaviour of system.*

Keywords: *Battery Energy storage system(BESS), Doubly fed induction generator(DFIG), grid power levelling, wind energy conversion system (WECS).*

1. INTRODUCTION

The use of renewable sources for electric power generation has experienced a huge face lift since past decade. Increasedeconomic and ecological woes have driven researchers to discover newer and better means of electrical energy. In this race, wind energy conversion systems (WECS) have stood ahead of other renewable energy sources like solar energy, which still lags behind owing to high cost per kilowatt-hour(KWh) of electrical power generated. Among all the available technologies for WECS, the doubly fed induction generator(DFIG) is most accepted because it combines the advantages of reduced converter ratings for power conversion and an efficient power capture due to the variable speed operation. An integrated WECS with DFIG is most popular option to harness wind energy due to varying nature and unpredictability of wind speeds. Generally, stator windings of DFIG are directly connected to the grid and the rotor windings are fed through bidirectional PWM voltage source converters(VSCs) to control the rotor and stator output power fed to the grid for variable speed operation. In a DFIG, both the stator and rotor are able to supply active power, but the direction of this power flow through the rotor circuit is dependent on the wind speed and accordingly the generated speed. The converter handles only around 25% of the machine rated power while the range of the speed variation is 33% around the synchronous speed. An effective control strategy addresses the dynamics of a DFIG-based variable speed wind turbine and the operation of the converters under sub-synchronous and super-synchronous modes of operation and during the transition period of these two modes. Although, DFIG has proven to be viable solution for high performance WECS, output power is highly fluctuating due to varying nature and unpredictability of wind speeds.

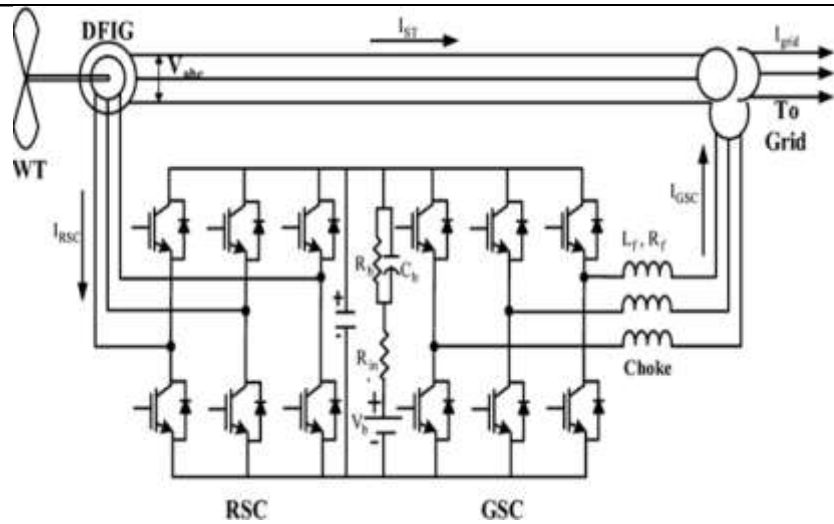

FIGURE 1. DFIG based WECS with Battery Energy Storage System

The block diagram explains overview of proposed system and the Variable Speed Drive has advantage of operating with reduction of fluctuations of power output. In this,a mathematical model for a grid connected DFIG is developed using back to-back connected PWM-VSCs with a BESS in the DC LINK [1] [2].The proposed grid power levelling control strategy is implemented in a stator flux oriented system, also taking into account other issues governing the satisfactory operation of a DFIG viz., UPF operation, optimized active and reactive powers transfer, and tracking the maximum power point of the wind turbine. BESS are employed for systems having ratings as high as 10MW [3].

2. PROPOSED CONFIGURATION AND OPERATION

Modern turbines evolved from the early designs and can be classified as two or three-bladed turbines with horizontal axes and upwind rotors. Today, the choice between two or three-bladed wind turbines is merely a matter of a trade-off between aerodynamic efficiency, complexity, cost, noise and aesthetics. Additional key turbine design considerations include wind climate, rotor type, generator type, load and noise minimisation, and control approach. Moreover, current trends, driven by the operating regime and the market environment, involve development of low-cost, megawatt-scale turbines and lightweight turbine concepts. The output power of the turbine depends on power coefficient and wind velocity. The output power and wind velocity has the linear relation.

The output power of the turbine is given by the following equation,

$$P_m = 0.5 * C_P(\lambda, \beta) * \rho A V^3 \quad ....(2.1)$$

Where

Cp = Power coefficient

A = Swept area of rotor blades

V = the wind velocity

$\boldsymbol{\lambda}$ = the tip speed ratio

β = the pitch angle

The power coefficient is defined as the power output of the wind turbine to the available power in the wind regime. This coefficient determines the “maximum power” the wind turbine can be absorbed from the available wind power at a given speed. It is a function of the tip speed ratio ($\boldsymbol{\lambda}$) and the blade pitch angle can be controlled by using a “pitch –controller” and the tip-speed ratio (TSR) is given as

$$\lambda = w\frac{R}{V} \qquad ...(2.2)$$

w = Rotational speed of the generator

R = Radius of blades

Hence, the TSR can be controlled by controlling the rotational speed of the generator. For a given wind speed, there is only one rotational speed of the generator which gives a maximum value of CP, at a given β. The characteristics of power coefficient (Cp) and TSR ($\boldsymbol{\lambda}$), blade pitch angle (β), as shown in Fig. 2.1.

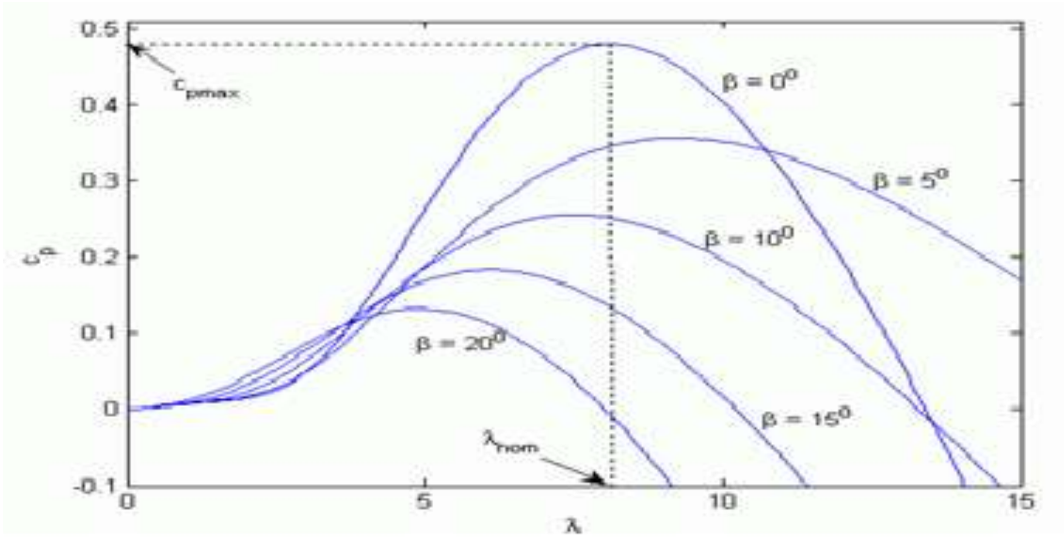

FIGURE 3. The characteristics of power coefficient (Cp) and TSR ($\boldsymbol{\lambda}$), blade pitch angle (β)

The mechanical power output of the wind turbine is mainly depending on the power coefficient Cp ($\boldsymbol{\lambda}$, β), it is very important parameter. The power coefficient given as below

$$\mathrm{Cp}(\lambda,\beta) = \mathrm{C1}\left(\frac{\mathrm{C2}}{\lambda+\mathrm{C8}\beta} - \frac{\mathrm{C2C9}}{1+\beta^3} - \mathrm{C3}\beta - \mathrm{C4}\beta - \mathrm{C6}\right) * \quad e^{\left(\frac{-c7}{\lambda+c8\beta}+\frac{c7c9}{1+\beta^3}\right)} + \mathrm{C10}\boldsymbol{\lambda} \qquad \text{... (2.3)}$$

The coefficients c1 to c6 are: c1 = 0.5176, c2 = 116, c3 = 0.4, c4 = 5, c5 = 21 and c6 = 0.0068. The cp-λ characteristics, for different values of the pitch angle β, are illustrated above. The maximum value of cp (C pmax = 0.48) is achieved for β = 0 degree and for λ = 8.1. This particular value of λ is defined as the nominal value (λ_nom).

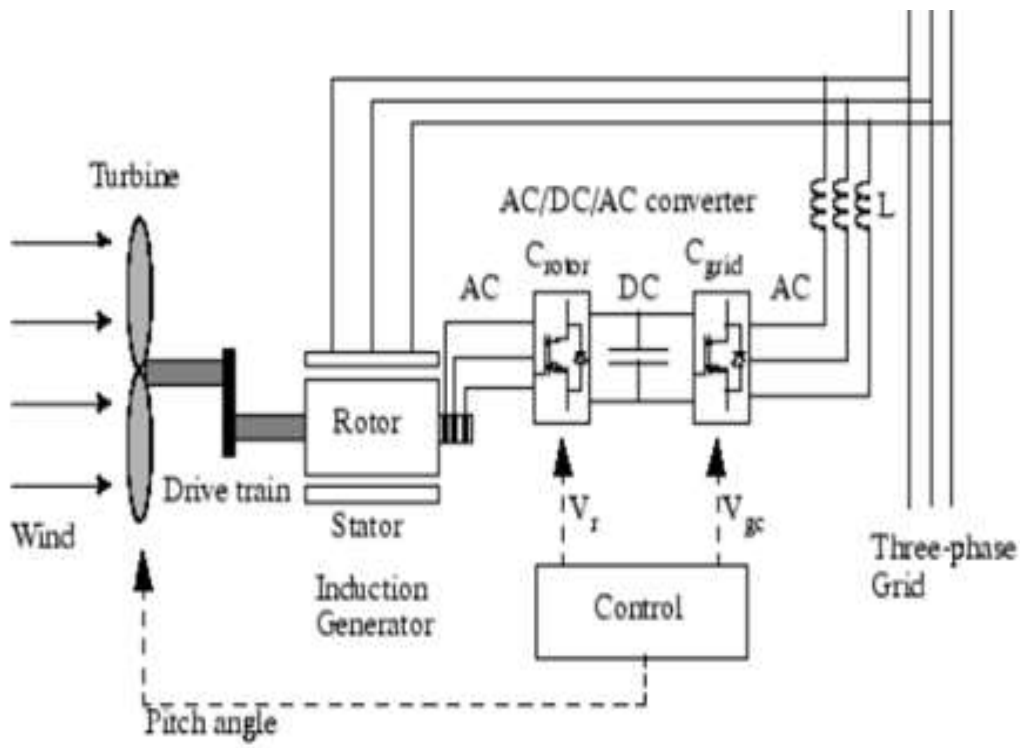

FIGURE 4. DFIG-based WECS in dc link for grid power levelling

3. SIMULATIONS AND RESULTS

The model of WECS
With BESS is shown in Fig is developed in the MATLAB- SIMULINK as described and results are presented to demonstrate its behaviour in different wind speeds.

The model of WECS with BESS is operated in three different modes are
1. Sub synchronous mode
2. Synchronous mode
3. Super Synchronous mode

In sub synchronous mode, wind speed is 8m/s and the rotor speed is 0.9pu.
In synchronous mode, wind speed is 10m/s and the rotor speed is 1pu.
In super synchronous speed, wind speed is 12m/s and the rotor speed is 1.2pu.

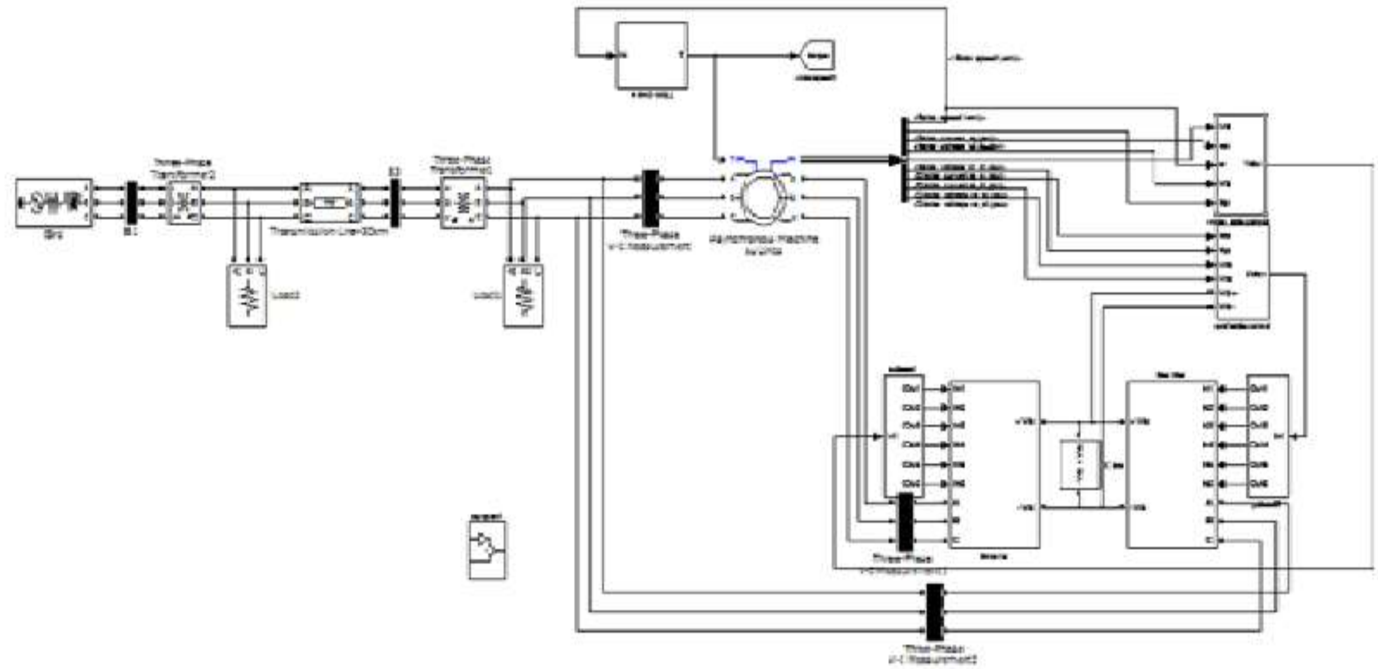

FIGURE 5. Simulink diagram of model of WECS with BESS

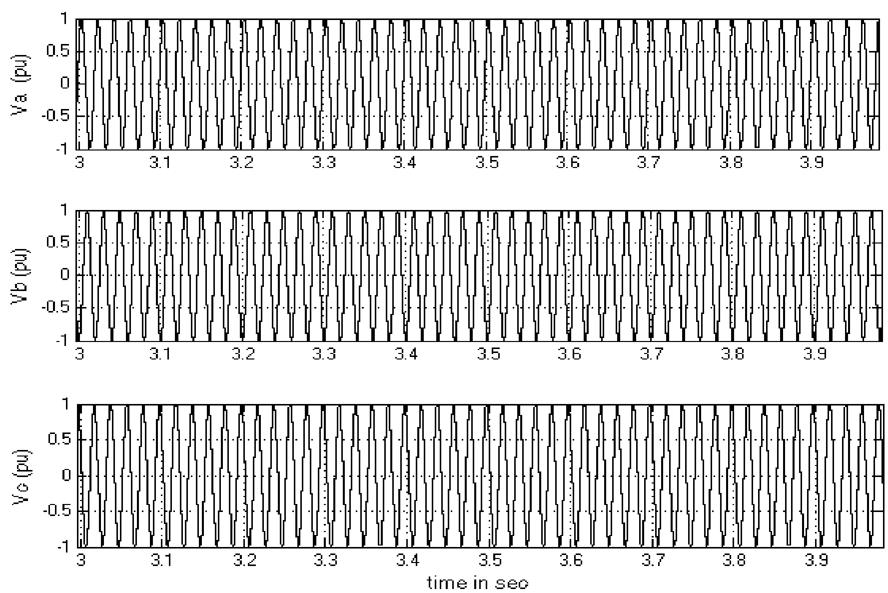

FIGURE 6. The stator voltage (V_{abc}) in all three modes

The purpose of Rotor side converter is control the rotor currents. The torque developed in machine is controlled by this current. The wind turbine output power and stator voltage controlled by the torque. In all three modes, the Rotor side converter current (I_{RSC}) is 1pu.

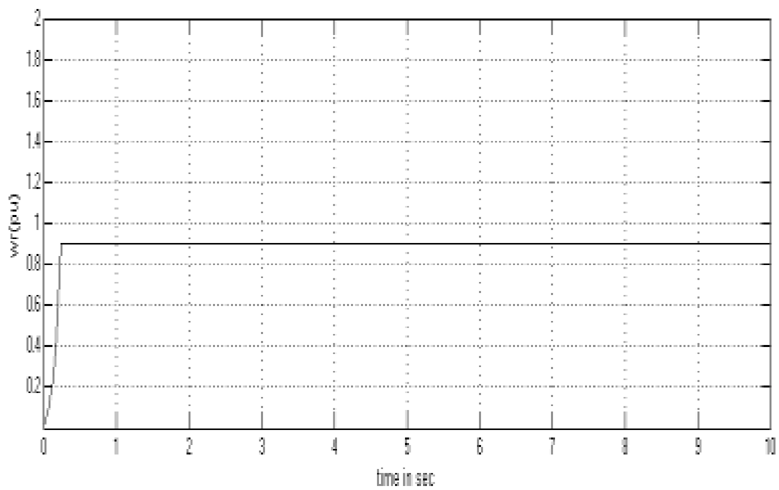

FIGURE 7. Rotor speed (w_r) in sub synchronous speed

The model operated in sub synchronous speed, in this mode, the machine operated as Motor and wind speed is less than the base wind speed. So the power is fed to the machine from the grid through converters. The rotor speed in this mode is 0.9pu.

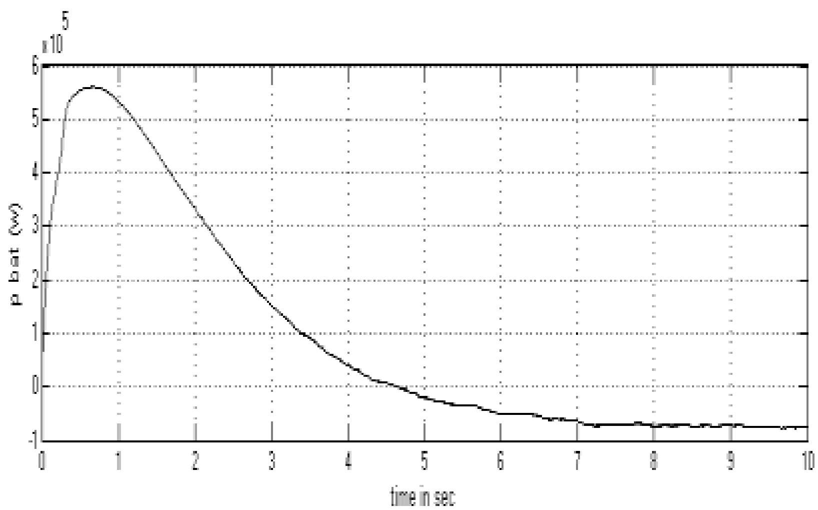

FIGURE 8. Battery power (P_{bat}) in sub synchronous speed

The model operated in sub synchronous speed, in this mode the power generation is less than average power then the battery discharges power to the grid and maintain the constant power on the grid. The battery discharges power to the grid, so battery power is negative. In this mode, the battery power is – 0.3pu.

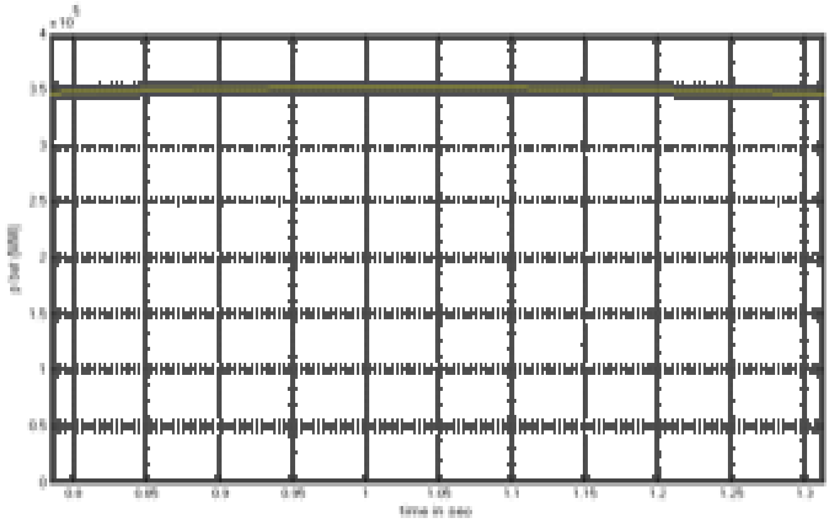

FIGURE 9. Battery power (P_{bat}) in synchronous speed

The model operated in synchronous speed, in this mode the power generation is not less than average power then the battery neither discharges nor stores the any power from the WECS. So the battery power is positive, then the average power supply to the grid and maintain the constant power on the grid. In this mode, the battery power is 0.3pu, as shown in Fig.

4. CONCLUSIONS

Power generation in wind energy conversion system is not constant, varying with wind speed. The power fluctuations on grid causes many problems i.e. power quality, power factor, voltage stability and power losses. The main aim of this project is to reduce the power fluctuation in wind energy systems and maintain constant power on the grid by BESS control strategy. A methodology to design the BESS has been proposed by considering the practical data at an installation point. The performance of the proposed control strategy ("grid power levelling") on a DFIG based WECS with BESS has been demonstrated under different wind speeds. It has been observed that DFIG based WECS with BESS demonstrates satisfactory performance under different wind speed conditions and gives approximately 70% of base power. In this project, considering some limitations on DFIG, the generator operated in below gusts speed. The existing control strategies and new proposed strategy "Grid Power Levelling" is satisfactorily implemented and power fluctuations on Grid had got reduced. Moreover, other important control strategies like the Maximum Power Point Tracking (MPPT) and unity power factor operation at the stator terminal are also satisfactorily observed. Placing a BESS in the dc link of a DFIG-based WECS proves to be a better implementation in terms of maintaining (70-75) % constant power at the grid.

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