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Wind Energy Conversion System Using Doubly Fed Induction Generator Integrated With Shunt Active Filter

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ABSTRACT: Recently a heaps of research and development is going on renewable energy sources and such that in this field of wind energy. The wind vitality is the favored for all renewable sources. In this proposed method, the classical wind generator will be replaced by the use of Doubly Fed Induction Generator (DFIG) technique which is integrated with Shunt Active Filter (SAF). The main aspire of prospect work is in the control of Rotor Side Converter (RSC) contribution for attaining maximum power extraction and to supply requires reactive power of DFIG. The Grid Side Converter (GSC) transfer the active power from the machine side converter into the grid through Shunt Active Filter for reimburses harmonics produced by nonlinear load. The proposed Wind Energy Conversion System using DFIG integrated with Shunt Active Filter is simulated by using *MATLAB/SIMULINK*.

KEYWORDS: Wind Energy Conversion System (WECS), Doubly Fed Induction Generator (DFIG), Nonlinear Load, Harmonics, Shunt Active Filter (SAF).

I. INTRODUCTION

Wind energy is an indirect manifestation of solar energy. Historically, wind energy was used for sailing ships and for generating small amount of mechanical power through wind mills. The advantage of using wind energy is that its potential as a source of power is reasonably good and that its capture produces no pollution. The problem associated with this type of energy is that it is in dilute form and the availability of the energy varies considerably over a day and with the season [1]. There has been a constant rise in the use of renewable energy resources. Global wind energy capacity soared by a fifth to 238GW at the end of 2011[2]. India being the 5th largest player globally, accounted for 16GW. Hence, an urgent need for substituting conventional energy sources by alternative (renewable) sources is exceedingly being felt. Such can be extracted from renewable resources such as solar, wind, tidal, biomass, hydro or any of the hybrid combination of these to meet the required power demand. A generator is a device that converts mechanical energy to electrical energy for use in an external circuit [3]. The doubly fed induction generator is an emerging trendsetting technology, presently used in some large wind turbines with variable wind speed operation. The two examples of DFIG are NEG Micon's 4.2-MW/100-m diameter machine and 2- to 3-MW GE machine [6]. The DFIG is admired system in which the power electronic interface controls the rotor currents to attain the variable speed obligatory for maximum energy confine in variable winds. The most attractive feature of the doubly fed induction generator is that only 20 to 30% of the power needs to pass through frequency conversion as compared with 100% in the variable-speed synchronous generator. The named so as because the motor is fed from both stator as well as rotor [8].

In this paper, the model of DFIG based variable speed direct drive wind turbine generating system WTGs is developed. The main feature of the proposed topology is that the energy storage elements, such as inductors and capacitors, can be reduced in order to improve the reliability, and reduce size and total cost. The basic structure, control

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design, and MATLAB/SIMULINK results are presented. The shunt active power filter based on current controlled voltage source type PWM converter has been proved to be effective even when the load is highly non-linear. Most of the active filters developed are based on sensing harmonics and reactive volt-ampere requirements of the non-linear load and require complex control. A new scheme has been proposed in which the required compensating current is determined by sensing load current which is further modified by sensing line currents only.

Power Quality (PQ) mainly deals with issues like maintaining a fixed voltage at the Point of Common Coupling (PCC) for various distribution voltage levels irrespective of voltage fluctuations, maintaining near unity power factor power drawn from the supply, blocking of voltage and current unbalance from passing upwards from various distribution levels, reduction of voltage and current harmonics in the system [4]. Conventionally, passive LC filters and fixed compensating devices with some degree of variation like thyristor switched capacitors, thyristor switched reactors were employed to improve the power factor of ac loads. Such devices have the demerits of fixed compensation, large size, ageing and resonance. Nowadays equipments using power semiconductor devices, generally known as active power filters (APF's), Active Power Line Conditioners (APLC's) etc. are used for the power quality issues due to their dynamic and adjustable solutions [5].

II. PERFORMANCE ANALYSIS

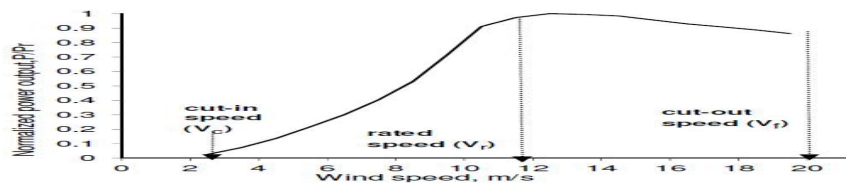


Fig1 Power output ~ wind speed

The proposed scheme is quite effective for wind power generation. Because of its small size it will face less turbulence from wind force and thus will tend to produce higher efficiency. Also, the cut-in value for generating power is at 3 m/s where traditionally it was 5 m/s. Thus it will maximize energy production over a specified time horizon.

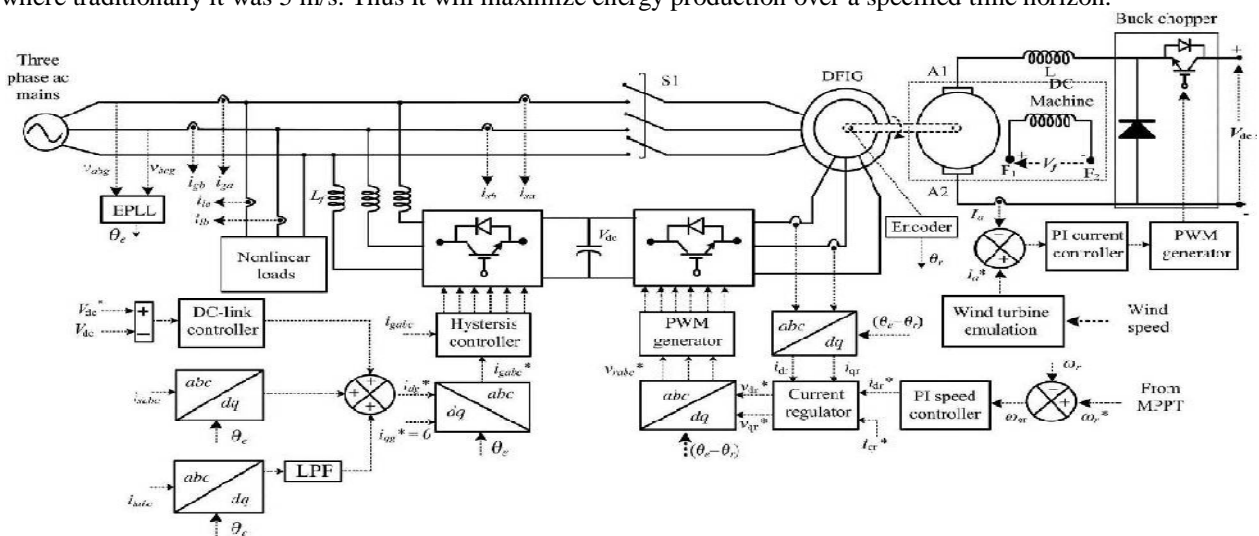


Fig2 Proposed System Configuration

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In the proposed system configuration the Power Quality (PQ) mainly deals with issues like maintaining a fixed voltage at the Point of Common Coupling (PCC) for various distribution voltage levels irrespective of voltage fluctuations, maintaining near unity power factor power drawn from the supply, blocking of voltage and current unbalance from passing upwards from various distribution levels, reduction of voltage and current harmonics in the system[1].

The output power of the wind turbine is given by, $P_{mech} = \frac{1}{2} \rho A_r C_p(\lambda) w^3$ where A is the swept area of wind turbine rotor. The performance of wind turbine is characterized by the non dimensional curve of coefficient of performance c_p and λ , as a function of tip-speed ratio. c_p as a function of λ & β is expressed by equation.

$$C_p(\lambda, \beta) = 0.5176 * (116 / (1 / ((\lambda + 0.08 * \beta) - 0.035 / (\beta^3 + 1)))) - 0.4 * \beta - 5) * \exp(-21 / (1 / ((\lambda + 0.08 * \beta) - 0.035 / (\beta^3 + 1)))) + 0.0068 * \lambda.$$

The tip-speed ratio is given by the expression, $\lambda = \frac{\Omega_r R_r}{w}$

Where w is the wind speed, Ω_r is the rotor speed, R_r is the rotor plane radius, ρ is the air density.

In general, $P_t = T_t W_m$

$$\text{So, Torque developed, } T_t = \frac{1}{2} \rho A_r \frac{C_p(\lambda)}{\lambda} w^2$$

III. OPERATING PRINCIPLE AND SYSTEM CONFIGURATION

The system consists of a DFIG and a back-to-back voltage source converter with a DC link capacitor. The back-to-back converter consists of a Grid-Side Converter (GSC) and a Rotor-Side Converter (RSC). The exclusive control feature of the DFIG is that simultaneous and decoupled regulation can be made for active variables (speed, active power, or torque) and reactive variables (voltage, reactive power, or power factor). When the rotor power is allowed to flow in both directions, the control can be realized over a wide range of the rotor speeds, above, below and at the synchronous speed. The rotor voltage equation is used for designing the rotor current controller. The stator voltage equation, determines the dynamic behavior of the machine. This equation, in the stationary reference frame, is furnished below. i_s and i_r are the stator and rotor currents in the influence of main flux saturation on overall peak currents in DFIG under grid fault is limited. Thus, the magnetizing inductance can be assumed to be constant when designing ride-through controllers and protection systems. "dq" theory modeling procedure is used here for the modeling of DFIG.

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°. A nonlinear load will be connected to the three phase system and a three phase shunt active power filter is connected to the system. By connecting the 3phase source with a nonlinear load we can observe the nonlinear currents in a,b,c coordinates. The nonlinear currents in a,b,c coordinates will be fed as input to the reference current generator. Inside the reference current Generator we are using CLARKE transformation theorem in which we are converting the a,b,c coordinates into dq coordinates. The currents would be separate simultaneously to oscillating and instantaneous components. The oscillating component of P and Q which are calculated from three phase source voltage and load current is filtered out using a low pass filter. Whole current in q axis will be used for harmonics elimination and reactive power compensation. Reference currents can be determined by Inverse Park transformation theorem. The reference current that will be generated from the reference current Generator will be fed to the control block inside which a hysteresis controller will be used, where it will compare the reference current with the current value measured from the circuit and will regulate the switching pulses which will be fed to the inverter. Gating signals that will be produced fed to the IGBT inverter to provide the firing pulses. Output of the Inverter will be fed to the circuit in order to compensate the harmonic currents. The p-q theory defines three instantaneous powers in three phase systems, with or without neutral conductor

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$$\begin{bmatrix} P_0 \\ P \\ q \end{bmatrix} = \begin{bmatrix} V_0 & 0 & 0 \\ 0 & V_d & V_q \\ 0 & V_q & -V_d \end{bmatrix} \begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix}$$

Where, p_0 - instantaneous zero-sequence power, p - instantaneous real power, q - instantaneous imaginary power. The instantaneous active and reactive powers for a three-phase three-wire system are defined as:

$$\begin{bmatrix} P \\ q \end{bmatrix} = \begin{bmatrix} V_d & V_q \\ V_q & -V_d \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix}$$

Where, p -Active power, q -Reactive power. V_d and V_q -Transformation of voltages. The same transformation matrices are used for the transformation of current; the current i_d and i_q are expressed as

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{1}{V_d^2 + V_q^2} \begin{bmatrix} V_d & V_q \\ -V_q & V_d \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix}$$

where, i_d and i_q transformation of currents both active power (p) and reactive power (q) defined above are composed of two components.

$$p = p_{ac} + p_{dc} ; q = q_{ac} + q_{dc}$$

where p_{ac} and p_{dc} represent the oscillating and average parts active power and q_{ac} , q_{dc} represent the oscillating and average parts reactive power.

$$\begin{bmatrix} i_{cd} \\ i_{cq} \end{bmatrix} = \frac{1}{V_{sd}^2 + V_{sq}^2} \begin{bmatrix} V_{sd} & V_{sq} \\ -V_{sq} & V_{sd} \end{bmatrix} \begin{bmatrix} -p + p_{loss} \\ q \end{bmatrix}$$

Where V_{sd} , V_{sq} transformed reference voltages.

IV. SIMULATION AND RESULTS

A model is constructed in MATLAB Simulink to create WECS using DFIG which is integrated with shunt active filter.

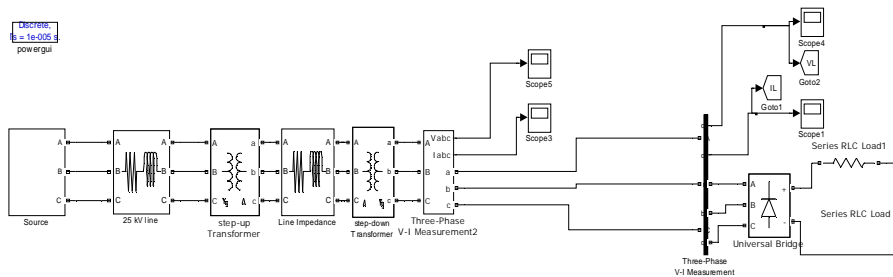


Fig3 DFIG with Nonlinear Load

Fig3 describe that the linear load give THD of 0.02%. The source voltage is connected with nonlinear loads with help of step-up transformer. The nonlinear loads inject harmonics. We used SAF to reduce the harmonics of nonlinear loads.

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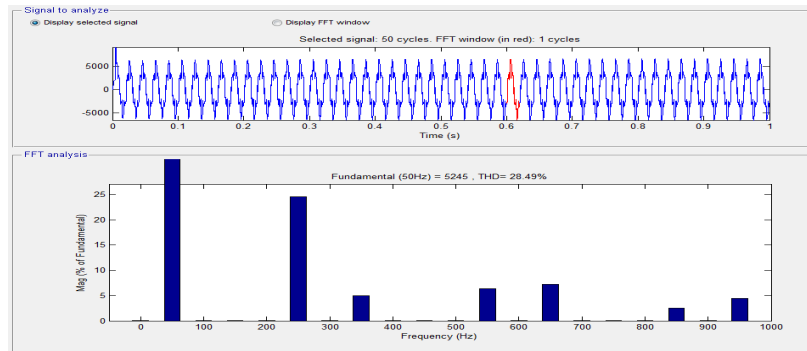


Fig4 THD for Nonlinear Load

Fig4 shows the THD of DFIG which is connected with nonlinear load. The THD was found by FFT Analysis. The DFIG also connected with grid.

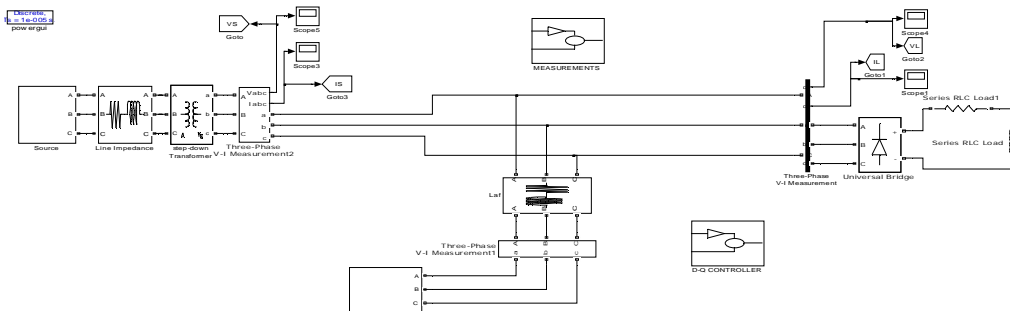


Fig5 DFIG integrated with SAF

Above figure describe the modeling of Shunt Active Filter by using d-q controller. To reduce the harmonics we have used the Shunt Active Filter. Also the DFIG is integrated with grid. The controller method is done by clark's transformation and also inverse clark's transformation method.

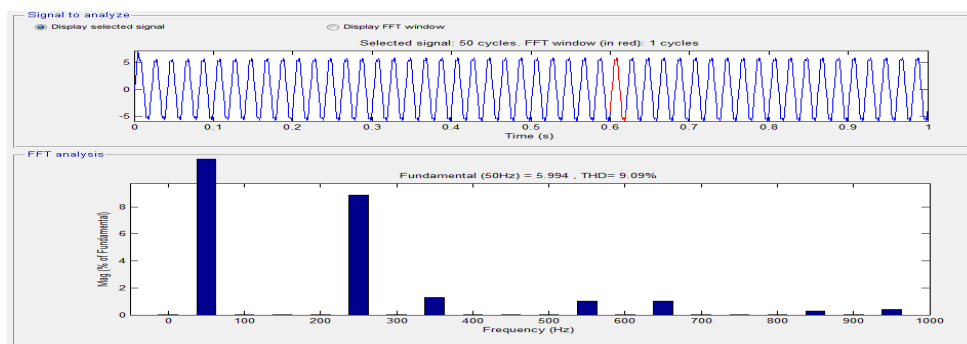


Fig6 THD of using SAF

By using Shunt Active Filter the THD reduces nearer to IEEE standard 519-1992.

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V. CONCLUSION

The model has been developed in MATLAB/SIMULINK environment. It is found from the simulation results that shunt active filter improves power quality of power system by compensating harmonic which mitigate the distortion and it also makes waveform sinusoidal. The THD of the observed output waveform is nearer to the harmonics limit imposed by IEEE standard 519-1992.

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