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Research Paper

Modeling and Implementation of MPPT based Wind Energy System Using Cuckoo Search

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Abstract

This paper presents adjustable speed generators for wind turbines. In order to improve the potential and performance of wind turbine system this paper proposes a concept DFIG. Generally wind nature is not fixed it varies linearly w.r.t time, hence, a MPPT controller is proposed in this paper. This paper presents the DFIG wind energy system. A Control strategy implemented and controlled by framing rotor reference frame axis in terms of direct and quadrature axis coordinates. A PI based RSC and GSC controllers are introduced to control the power through the wind system to grid. This proposed model is implemented and verified by using Matlab/Simulink.

Keywords: *Cuckoo Search; Doubly Fed Induction Generator (DFIG); MPPT Controller; Wind System.*

1. Introduction

Increased demand of sustainable power source into power grid brought forth a few difficulties those are knowledgeable about coordinating such sources among themselves and in addition with the grid. In spite of the fact that the vitality got from such sources is condition agreeable, the power and voltage acquired from such sources shifts haphazardly with the variety of climate. Renewable energy has been developed due to fossil fuel weariness and environmental problems. In contrast to other renewable energy, such as solar energy, blowing wind power [1] is somewhat better suited for some applications with relatively low cost. To provide stable and reliable electrical power to rural and remote areas, stand-alone based small scale wind power generation system is more suitable. In the present scenario, wind energy system plays a key role in non-conventional energy systems, because of its vast construction and economical. However, wind energy presents an erratic nature. So, the electric power produced by a connected wind system varies brutally due to rapid variation of wind speed. For this reason, research to extract the maximum power out of wind energy [8] is necessary to making wind energy sources much more viable, effective and attractive. This can be achieved by a MPPT technique [9] which is required to compensate the low efficiency.

2. Wind Turbine system

Wind Energy system plays a key role in non-conventional power sources, In this mainly wind energy is converted into electrical energy it is not possible. but possible one is wind energy is converted into mechanical energy and then mechanical energy is converted into electrical energy. wind as we know, wind turbine converts Wind energy to mechanical energy due to wind energy is given to the wind turbine blades ,blades will be rotated and shaft also rotated, in this process output is mechanical energy and then shifted by the gear box, hub to the shaft, shaft means Rod when connected from wind turbine to generator, in this process output is electrical energy. with the help of Generators [2]. The group of wind turbines called as wind form. The wind generator system using DFIG is shown in figure 1.

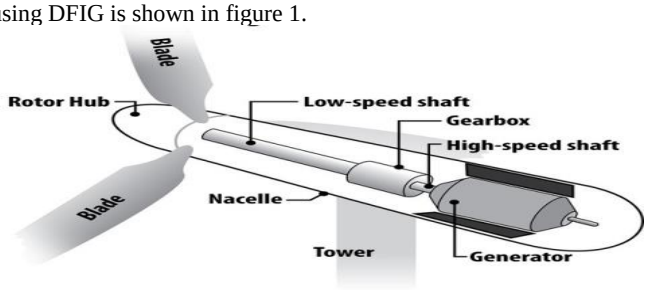


Figure 1: Basic Wind Turbine System

The Mechanical power from the wind turbine system is expressed as:

$$P_m = \frac{\rho A}{2} V_{wind}^3 C_P(\lambda, \beta) \quad (1)$$

Where, C_P is cofficient of Power.

ρ is swept area, A is air density, V_{wind} is speed of Wind, λ is tip speed ratio, β is pitch angle and $\frac{\rho A}{2} V_{wind}^3$ is equal to the kinetic energy.

3. SCIG and DFIG system

a. SCIG System:

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First of all abbreviation of SCIG is squirrel cage induction generator. The grid connected SCIG system is shown in figure 2(a). Basically, SCIG is used for a constant speed generator, in this mainly consists of three stages. First stage is wind form stage that is (less voltage stage), second stage is distribution stage that is (intermediate voltage stage) and last stage is transmission stage that is (more voltage stage).in this designing rotor conductor bars or windings are short circuited and also stator windings are directly connected to the grid so this called as straight forward conversion technique method. This also called as an open loop control system. In this wind power increases and also correspondingly output power fixed. Some cases wind turbine rotates highly but output power not changed because our SCIG generator rotates fixed speed that's why output power not varied. in this mainly employed thing is pitch angle. Pitch angle is in order to control the speed of the turbine blades.

The speed of induction generator slip changes only few percent w.r.t changes in wind speed.in this main disadvantage of SCIG is reactive power compensation that is connected by externally, it is required to keep the line of distribution voltage and to stop total system from overloaded. in order to inject the reactive power to the line.in SCIG system voltage drop is more in distribution line, which is effect an over load problem. And another problem in SCIG is speed cannot be controlled because generator rotates constant speed. But there is no speed control mechanism for the generator. Wind turbines based on a SCIG [4] are typically equipped with a soft-starter mechanism and an installation for reactive power compensation, as SCIGs consume reactive power. it is simple operation of construction and more reliable and cheaper.

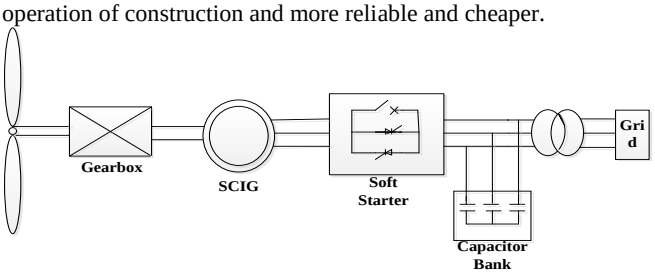


Figure 2(a): Structure of SCIG System

b. Pitch Angle Control:

It is nothing but an angle between a blades and height of the tower. It is denoted by the letter β (Beta). in this paper pitch angle is prefer to only SCIG wind turbine system. Because in SCIG system a generator is fixed speed of operation and also output power will be fixed. that output value is called as nominal power.in some cases blades rotates highly also output power varies in slighty,in this situation pitch angle control is achieved. Note that when the wind speed is changing this means the rotational speed of the turbine is fixed .this is required to keep the rpm of the generator fixed. this reason for control pitch angle. Whenever a from output power will be exceeding the nominal value pitch angle can be controlled. Pitch angle is control a rotation of the blades.it works only nominal speed is below the wind speed. Pitch angle varies only some degrees maximum cases zero to thirty degrees. The output power varies only within the limits. The schematic diagram of the pitch angle control as shown in given below figure.

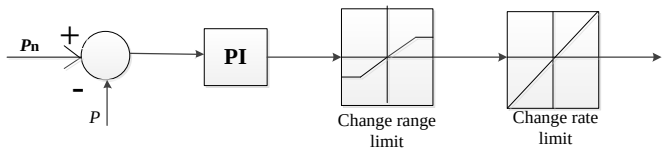


Figure 2(b): schematic diagram of Pitch Angle control

c. DFIG System:

First of all abbreviation of DFIG is doubly fed induction generator. Generally it also acts as a closed loop system. DFIG is most famous track in wind energy purpose. this is variable speed of operation of the generator in wind power system. DFIG wind power system consists of a slip ring induction generator and back to back converter like ac to dc and then dc to ac, dc link switches(IGBT) based pulse width modulation. The generator speed can be varied in slight variations. this dynamic slip control is employed. Slip can be controlled by external resistance.in this mainly consists of some power electronic converters are used why because from the line the leakage rotor current will be given to the generator via power electronic converters, because here no power will wasted. here using these two converters are like rectifier and inverter.

Back to back converter divided into two stages like stator side converter stage and rotor side converter stage. in these stator terminals are direct connected to grid via transformer. and rotor terminals of the generator is connected through brushes and slip rings at constant frequency. both converters for source of voltage converters. these two converters are used for balance a grid voltage and generator rotor voltage and also maintain constant frequency from grid to generator. DC link capacitor is placed in between converters. Here no external reactive power compensation is required. But to completely remove reactive power compensation, active and reactive power self dependent. First of all control and then focus on controllers, in which self dependent of reactive and power. In this RL series choke is used for control stator side converter control. the structure of DFIG back to back converter is shown in figure 2. Generally DFIG is one of the types in induction generator. the back to back converters [3] in DFIG are helps to control and recycle the rotor power.in this converters are used that's why automatically cost is high but improve power and life period of generator.

The mathematical analysis for the DFIG motor is implemented by using the differential equation approach and it is expressed as,

$$V_s = R_s I_s + j\omega L_s I_s + j\omega_1 L_m (I_s + I_r + I_{rm})$$
$$V_r / s = \frac{R_s}{s} I_s + j\omega L_s I_s + j\omega_1 L_m (I_s + I_r + I_{rm}) \quad (2)$$

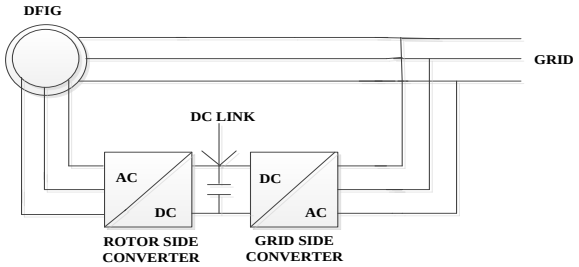


Figure 2(c): Structure of DFIG system

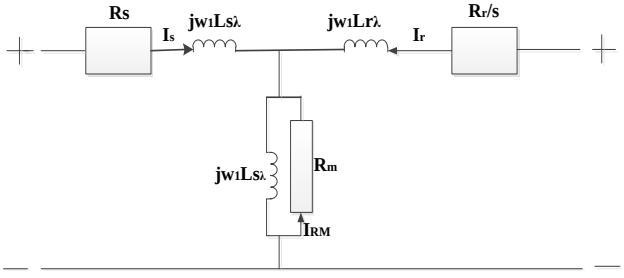


Figure 3: Equivalent circuit of DFIG

The closed loop control diagram for rotor side converter is shown in figure 4. The outer loop of this converter is used to control active and reactive powers of the system and it generates the direct and quadrature axis reference currents. Inner loop of the DFIG RSC is to generate the gate signals through PWM generator by comparing the reference currents with actual system currents [5]-[6].

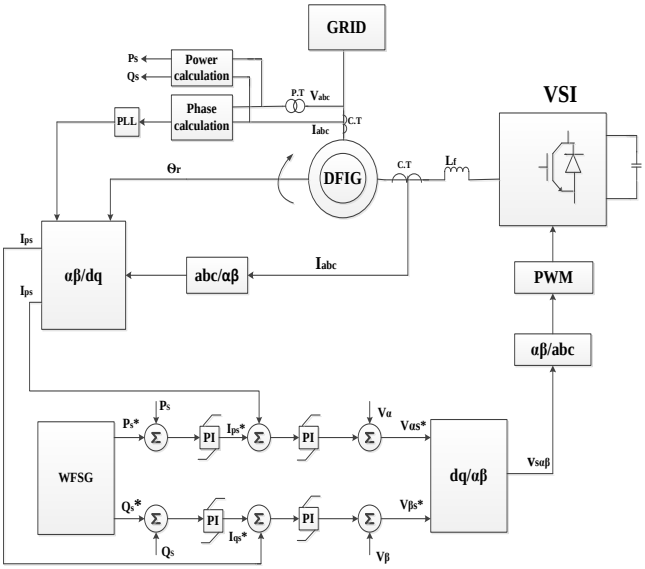


Figure 4: Control Diagram for the rotor side controller

Control diagram for grid side converter of DFIG system is shown in figure 5. In this, inner loop of controller is used to generate direct axis reference current by comparison of DC link reference voltages. The quadrature axis reference current component is generated by use of reactive power of DFIG system [7]. The gate signals required for the GSC converter is generated by PWM technique with the help of direct and quadrature axis component currents.

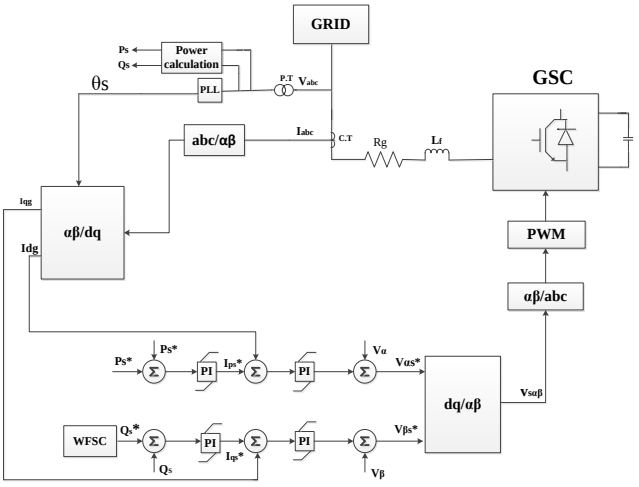


Figure 5: Grid side controller (GSC) scheme

4. Cuckoo search algorithm

Many nature inspired evolutionary algorithms have been developed for optimization in the past few years. These algorithms usually work based on a random search in some acceptable search region depending on the problem to be optimized. But the search is not truly random because there will be some mechanism in the algorithm which guides the search so that the solution vector gets improved with iterations [10]. Two crucial basic characteristics of these modern met heuristic algorithms are intensification (Exploitation) and diversification (exploration).

The flowchart of the proposed method is shown in figure 6. First, all constants and variables, namely the voltage, current, power, number of samples and the value of b is initialized. Using the present value of voltage and current, the power is calculated. The new value of voltage and power are stored in the voltage and fitness arrays, respectively. Furthermore, before the start of every iteration, a check is performed to determine if the samples have already achieved convergence or otherwise. If the samples have converged to MPPT [11], they will merge as a same value and so does the respective power.

Table 1: Scig-Sytem Parameters

Parameter	**Value**
Nominal Wind Speed Vw	12m/s
Nominal Active Power Pnscig	0.85MW
Distribution Line Voltage Vdis	12.5e3
Grid Voltage Vgrid	100e3 V
Grid Frequency fgrid	50 Hz
Bus Voltage of the Wind Turbine Vwt	575 V
Generator no.of pole pairs np	4
Resistance of the Stator Rs	0.0048p.u
Leakage Inductance of Stator Ls	0.1248 p.u
coupling Inductance of Stator to Grid Lc	0.13 p.u
Nominal DC-link Voltage Vdc	4e3
DC-link Capacitance C	2200e-6
Referred Rotor Resistance Rr	0.0044 p.u
Referred Rotor Leakage Inductance Lr	0.1791 p.u
coupling Resistance of Stator to Grid Rc	0.012 p.u

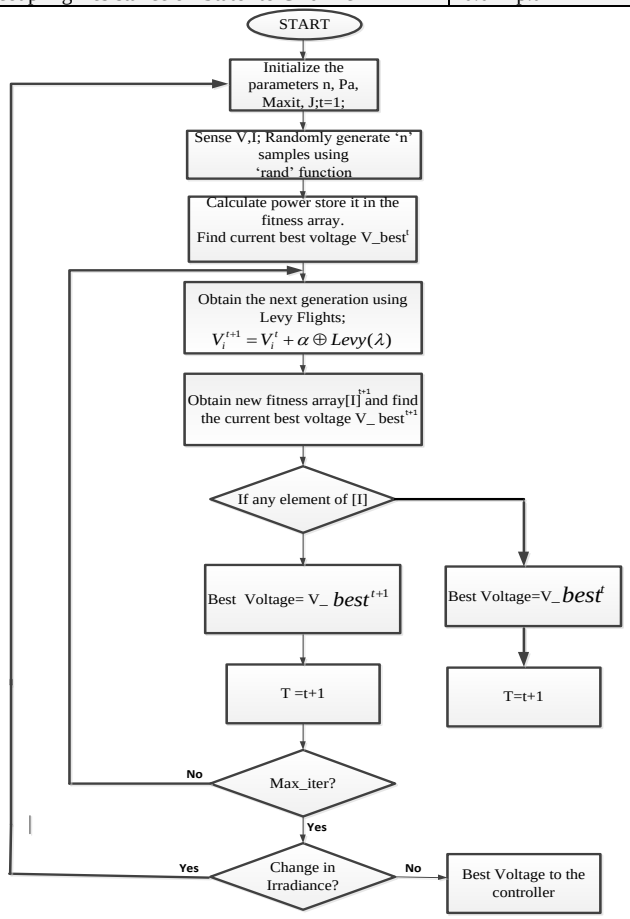


Figure 6: Flowchart for Cuckoo MPPT

If the samples do not converge, all the power values of the corresponding samples are measured and are stored in the fitness array. By evaluating the array, the sample with highest power is chosen as the best sample. Thereafter all other samples are forced to go towards this best value. The step sizes are calculated by performing the Levy flight as described by equations.

$$V_i^{t+1} = V_i^t + \alpha \oplus levy(\lambda) \quad (3)$$

$$S = \alpha_o (V_{best} - V_i) \oplus levy(\lambda) \quad (4)$$

5. Simulation result and discussion

The experimental results wind turbine emulator system as from the figures 1 and 2. The wind turbine model is designed by the mathematical model analysis.

Case 1: Wind Turbine System with SCIG Generator.
A SCIG based wind system is implemented in Matlab/Simulink, the performance of this system is investigated by choosing the ramp type wind speed. In this mainly observe speed of the wind, speed of the generator, active power, reactive power, and also pitch angle. Firstly wind speed this is input speed this is given the generator speed varied by the wind speed that is depending upon the wind speed and then power. Observe initial fluctuations in the results t=0 to t=0.1 s is due to original situations.in early generator speed is set at slip -0.01p.u.

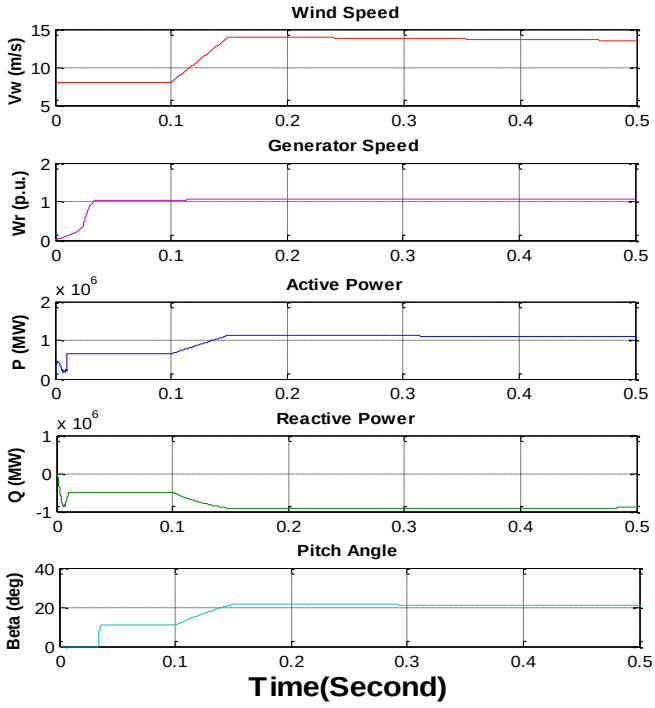


Figure 7: Simulation Result for Wind Turbine System with SCIG generator:wind speed vw,generator speed,active power P, reactive power Q, and pitch angle β.

Case 2: Wind Turbine System with DFIG Generator
A DFIG based wind system is implemented in Matlab/Simulink, the performance of this system is investigated by choosing the ramp type wind speed parameters of the DFIG wind power system as shown in Table 2, it allows peak output power in the lack of reactive power source. And also autonomous of reactive and active power is reached. in this mainly observe wind speed, active power, DC-link, generator speed. Whenever compared to SCIG, DFIG gives better power performance. But cost of maintenance is high[12-16].

Table 2: System Parameters of DFIG

Parameter	Value
Nominal Speed of Wind V_w	10 m/s
Nominal power of Apparent S_e	1.66 MVA
Nominal Power of Active P_{nDFIG}	1.6 MW
Grid Voltage V_{grid}	100e3 V
Generator no.of pole pairs n_p	4
Frequency of Grid *f*	50 Hz
Distribution Line Voltage Vdis	12.5e3
Bus Voltage of Wind Turbine V_{wt}	575 V
Resistance of stator R_s	0.0071pu
Leakage Inductance of Stator L_s	0.171pu
Resistance of Rotor R_r	0.005pu
Leakage Inductance of Rotor L_r	0.156pu
Mutual Inductance L_m	2.9pu
Nominal DC link Voltage Vdc	1.2e3
Nominal Equivalent capacitor C	10e-6
Maximum C Converter Current Icon	0.5pu
Inertia Coefficient of the System H	5sec
Generator Friction Damping F	0.01pu
Power Factor Pf	0.01pu

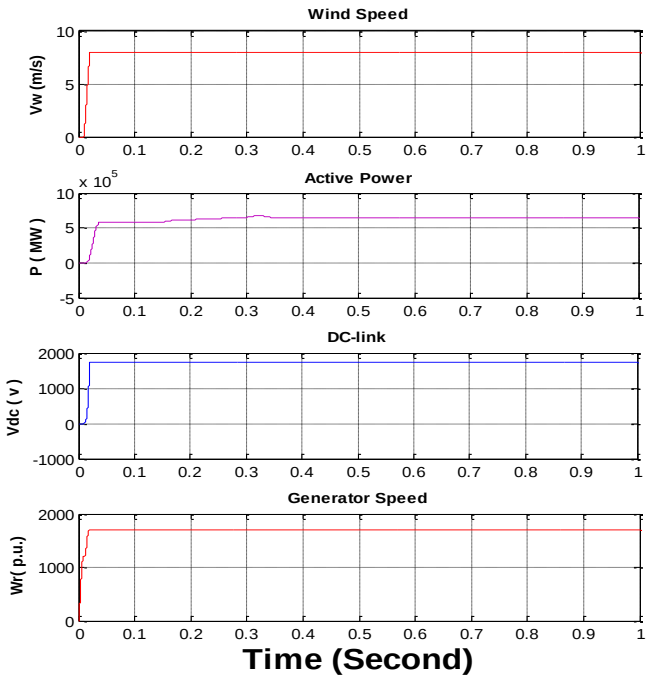


Figure 8: Simulation Result for Wind Turbine System with DFIG generator: Wind Speed, Active Power, DC-link, Generator

Case 3: DFIG based Wind Turbine System with Cuckoo MPPT Controller.
in this mainly observe Wind Speed, Active power, DC link, Generator Speed. By using this method Active power is improved when compared to DFIG above method this gives better results.

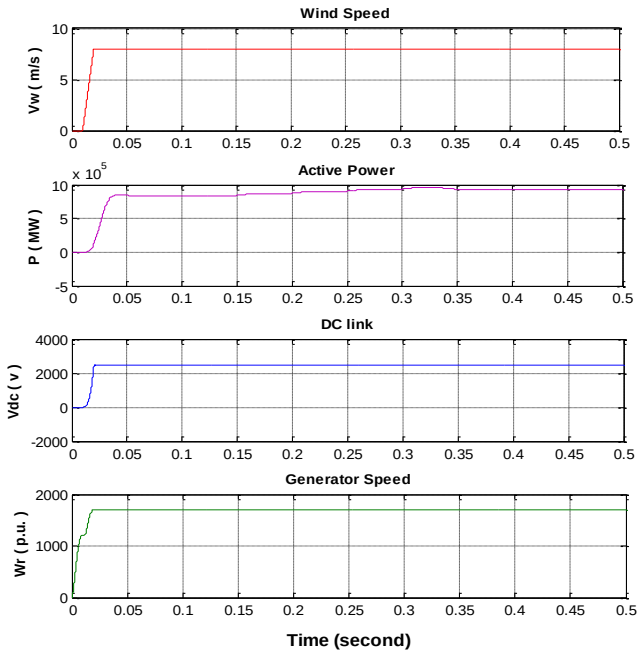


Figure 9: Simulation Result for DFIG based Wind Turbine System with MPPT Technique

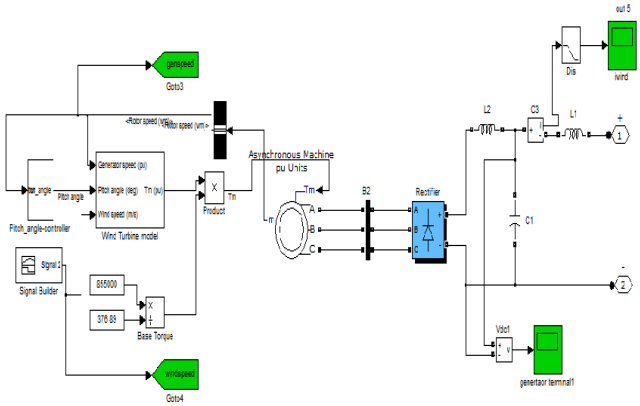


Figure 10: Simulation for wind power system of SCIG and DFIG

6. Conclusion

This paper proposes a DFIG based Wind system which control is assured by two PI regulators which are applied in order to control the active and reactive power exchanged with the grid. The best active power rhyme rotor speed has been proposed for wind model.in SCIG additional reactive power basis to maintenance grid voltage. But in DFIG system there is no need of reactive power source to keep voltage of the distribution line. And also an MPPT control method is introduced that attempt to get the peak from the energy conversion system despite of fluctuating wind conditions. To verify the validity and the effectiveness of the proposed MPPT control methods, simulation models are built with Matlab/ Simulink.

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