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Modeling and Simulation of Solar PV and DFIG Based Wind Hybrid System

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Abstract

The increasing energy demand and depletion of fossil fuels has risen in awareness of searching for alternative energy source thus the inexhaustible solar and wind energy is becoming an interesting topic which has grabbed the attention of researchers to make it sustainable power. The objective of this paper is to provide sustainable power for rural areas and remote places.This paper gives the architecture of hybrid system. The proposed system consists of solar PV and Doubly Fed Induction Generator (DFIG) based wind turbine. In Solar PV MPPT technique is used to maximize the power and boost converter is used to rise the DC voltage of solar PV and fed to the three phase PWM inverter. The DFIG has two controllers Rotor side control and Grid side control. Rotor side converter and Grid side Converter have the capability of generating or observing reactive power and to maintain constant rotor speed, and controls the DC-link voltage, controller for boost converter, inverter AC-DC-AC is implemented using vector control method. Simulation study of the proposed system is carried out with MATLAB Simulink and simulation results are provided.

Keywords: Hybrid system; DFIG; PV cell; MPPT; Converters;

1. Introduction

Hybrid is a combination of two or more energy sources which generates efficient energy power because we are combining more than one energy source. Now a days Hybrid Energy System(HES) have more scope especially in rural and remote areas because these areas do not benefit from the grid supply and because of increased demand, global warming, depletion of non-renewable energy sources are compel to go for renewable energy sources. Many

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hybrid systems are there among them Solar and wind energies gives better results because these two energy sources are complimentary in nature. The drawback of solar and wind are intermittent in nature this make unreliable but combining the solar and wind energy reliability of the system can be enhanced.

Often solar and wind energies are complimentary in nature when there is no sun there is plenty of wind vice/versa. In present scenario, renewable energy increasing .As government giving subsidiary for solar panels. We are using MPPT for solar to track maximum power point it is very much essential for solar array .From the review paper [1] Many MPPT's are discussed. Autonomous wind will be available in rural areas and we can make use of it. DFIG based WT is used which is normally preferred for larger scale power generation [2].The converters that are used in this topology uses only 20-30% of the total capacity of the output power [3]. Other major advantages are we can independently control the both active and reactive power .Converter control employs d-q vector.

2. Proposed system

Fig. 1 shows the block diagram of the proposed system.The output of solar panel is connected to boost converter to step up the dc voltage and fed to the three phase inverter and output of the inverter connected to the grid and output of the DFIG is directly connected to the grid.
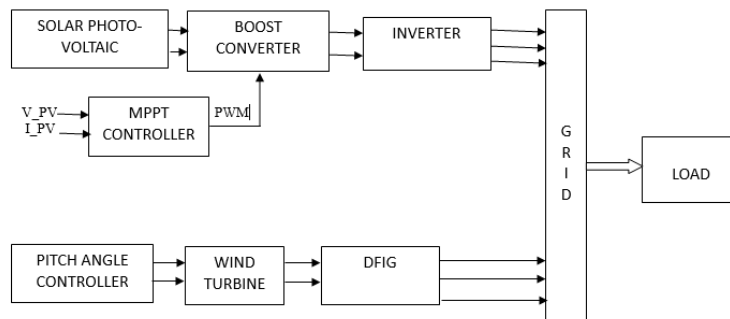

Fig. 1. Proposed system block diagram

3. Solar PV system description:

In PV system sun light energy is converted into electricity based on the concept of photovoltaic effect .The photo current depends on irradiation and temperature. If irradiation is higher current released by the cell will be more.

The equivalent circuit of a Photo Voltaic cell is shown in the Fig. 2. An ideal solar cell is represented by a Current source and a diode parallel with it. However no solar cell is ideal there by series resistance Rs which has very small value and Rsh is the equivalent shunt resistance whose value is very high. The PV cell current equation (1) as follows.

$$I = I_{pv, cell} - (Io [e (v + IRs / V_T) - 1] + V + IRS / Rp) \qquad (1)$$

Where Ipv, cell is the current generated by the incident light, depend on the solar radiation and cell temperature. Io is the reverse saturation or leakage current of the diode, VT is the thermal voltage
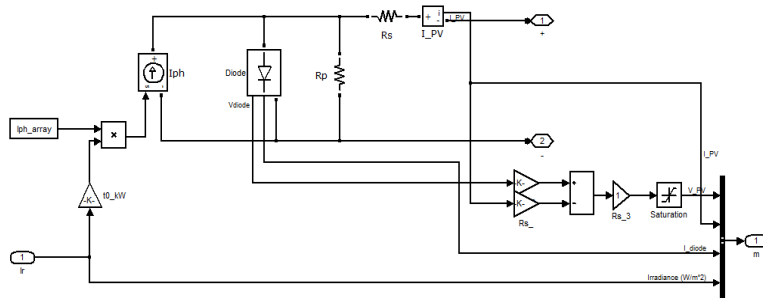
Fig. 2. Simulink model of solar cell using single diode

4. Evaluation of MPPT algorithm

It is very important to operate PV energy conversion system to maximum power point to obtain maximum power output from PV system. In this paper , incremental conductance method. Is used to obtain Maximum power point when.

$dp / dv = 0$ where $p = v*i$

$d(v*i)/dv = i + v*di/dv = 0 = =di/dv = -i/v.$

The integral regulator minimizes the error $(di/dv + i/v)$

Regulator output = duty cycle correction.

Algorithm of incremental conductance is as follows

Step1: sensing the voltage and current from solar panel and given to MPPT controller

Step2: MPPT controller compares the present with past values of the voltage and current which gives the difference ΔV and ΔI

$\Delta V = Vnew – Vold$; $\Delta I = Inew - Iold$

Step3: The maximum power point is tracked by considering $\Delta I/ \Delta V$ slope

step4: Adding the instantaneous conductance i/v to incremental conductance which gives the error signal

$e = i / v + di/dv$

Step5: This error given to PI controller to minimize the error or drive e to zero.

Step6: The PI controller generates the duty ratio which is given to the comparator to generate PWM pulses, the generated PWM pulses given to the switching device of the boost converter.

Step7: The above steps will be repeating till the maximum power reached.

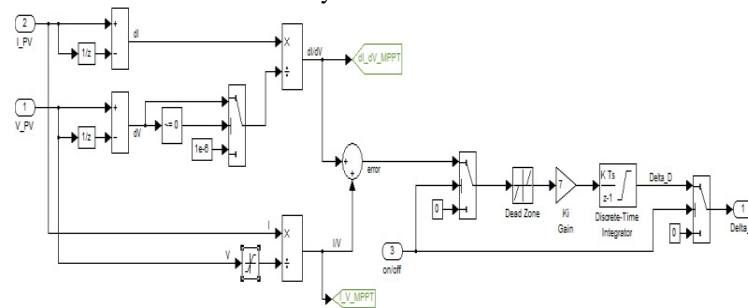Fig. 3 shows the implementation of MPPT in solar system.

Fig. 3. MPPT Control Model In Simulink

5. Boost converter

A boost converter is a dc to dc power converter with output voltage is greater than input voltage switch may be

IGBT, MOSFET, BJT etc... The boost converter contains at least two semiconductor devices. The output of the boost converter is given to the three phase inverter. The MPPT controller gives the PWM pulses to the IGBT to maintain constant output voltage.

5.1 Design Equations

Inductor: The inductor must always have a higher current rating than the maximum current because the current increases with decreasing inductance.

$$L = \frac{Vin*(Vout - Vin)}{\Delta Il * fs * Vout} ....(2)$$

Vin = typical output voltage,Vout = desired output voltage,fs = minimum switching of the converter,ΔIl = estimated inductor ripple current,Iout = maximum output current necessary in the application. A good estimated inductor ripple current is 20% and 30% of the output current.

$$\Delta IL = (0.2 - 0.4)*Iout(\max)\frac{Vout}{Vin}………...……....(3)$$

Output Capacitor: With External compensation, the following equations can be used to adjust the output capacitor values for a desired voltage ripple.

$$Cout(\min) = Iout(\max) \ \frac{Iout(\max) *Vout}{fs * \Delta Vout} ....(4)$$

Cout(min) =minimum output capacitance ,Iout(max) = maximum output of the application.

6. DC-AC three-level NPC inverter

Three-level Neutral Point-Clamped inverter is used in this work as shown in Fig 4. The three phases of the inverter share a common DC bus. NPC inverter consists of two series-connected capacitors C1 & C2. The DC-link capacitors divide the DC bus voltage into three levels; namely +0.5 Vdc, 0 and -0.5Vdc .There are two complementary switch pairs (S1a, S1'a) and (S2a, S2'a) and two clamping diodes (D1a, D1'a) per phase present in this inverter. The use of NPC inverter reduces the harmonics in the stator voltage [6].In order to obtain three levels across 'a' and 'n'. There are three switch combinations as shown in Table 1.

Table 1. Switching sequence of inverter

$S1_a$	$S2_a$	$S1'a$	$S2'_a$	Van
1	1	0	0	+0.5 Vdc
0	1	1	0	0 Vdc
0	0	1	1	- 0.5Vdc

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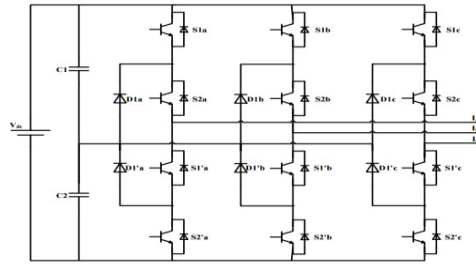*K. Rajesh et al. / Procedia Technology 21 (2015) 667 – 675* 671

Fig. 4. Three-level Neutral Point-Clamped inverter

7. Wind energy conversion system (WEC) system

Building blocks of WECS are wind turbine, doubly fed induction generator (DFIG), and two masse drive train. pitch angle controller, back to back converters.

7.1 Wind turbine model

Wind turbine converts the kinetic energy of the wind into mechanical energy transmitted by shaft. In this paper, prebuilt wind turbine model in Simulink is used to provide torque to the generator.

7.2 Doubly fed induction generator

In WECS, wind turbine is coupled with a Doubly Fed Induction Generator. A slip ring Induction Generator (Asynchronous machine wound rotor) block is taken in Simulink. Sign of the torque input determines whether the machine operates as a generator or as a motor. If sign of torque is positive, it works as motor and if the sign is negative, it works as a generator.

7.2.1 Pitch angle controller

To restrict rated power at high wind and at low wind to accelerate turbine faster we need a pitch angle controller The pitch servo is modelled as equation 5[5] . When the generator speed exceeds rated speed, the pitch control is comes into picture in order to maintain rated value.ω^{ref}=1.1pu.

$$\frac{d\beta}{dt} = \frac{-(\beta ref - \beta)}{T\beta} ....(5)$$

8. Rotor side controller

To maintain stator voltage and frequency constant require a variable voltage and frequency of the rotor so this requires converters and control circuit to supply the rotor with variable frequency and voltage to maintain constant stator frequency, and also uses the rotor currents (idr and iqr), so we require variable PWM pulses to generate theses pulses we comparing reference speed(1p.u) with actual speed and given to PI controller to regulate the rated speed of the rotor (in this paper, the stator-flux vector is calculated using Us)[4]. To operate machine at unity PF reactive power is set to zero. In this scheme vector control principle is used. Converting dq0-abc frame given to the

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comparator with triangular wave as carrier to generate pulses. Fig 5 shows the rotor control scheme.

9. Grid side controller

Grid side controller is used to maintain DC-link voltage.   Fig. 6 shows the control strategy of the grid side controller. The converter control operates in the grid-voltage oriented reference frame which is a synchronously rotating reference frame, with its direct-axis oriented along the grid-voltage vector position [2]. To regulate DC-link voltage PI controllers are used. The below equation which describes the dynamic behaviour of the DC-link capacitor as equation 6.

$$Cdc * \frac{dUdc}{dt} = ios - ior\ldots\ldots\ldots\ldots\ldots(6)$$

Where ios and ior are the DC-link currents of the grid and rotor side converters, respectively.
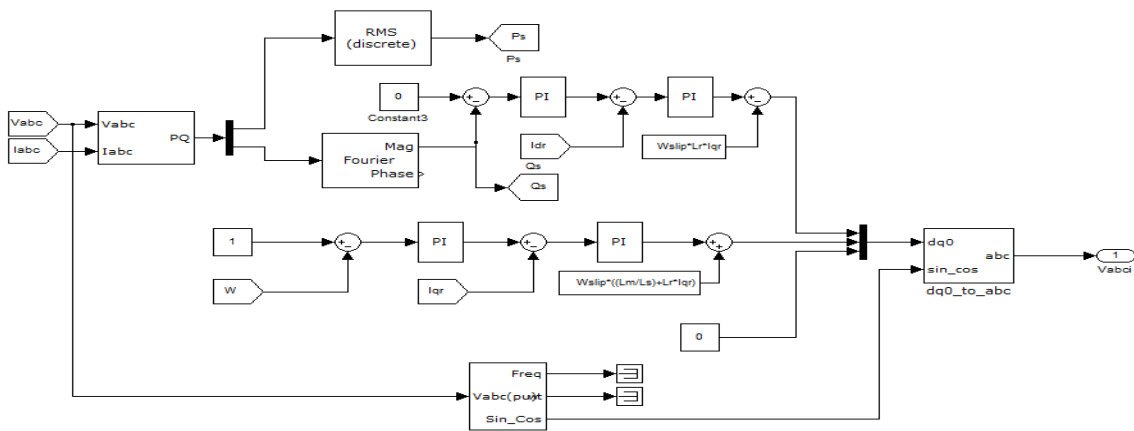

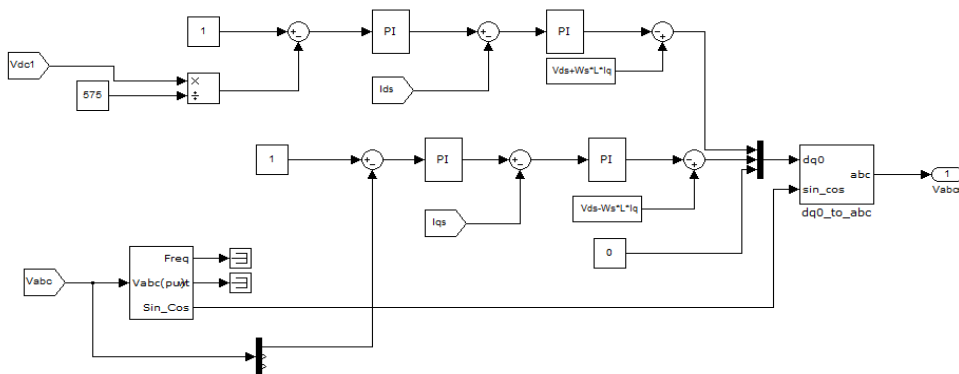Fig. 5. Rotor side controller in Simulink

Fig.6. Subsystem Grid side Controller in Simulink

10. Hybrid system

In Hybrid system number of electrical power generators and electrical power storage components are combined together to meet the electrical power demand of remote as well as rural area or even a whole community. Tt is also used as a standalone power system, is an autonomous system that supplies electricity to the user load without being connected to the electrical power grid In this paper Solar PV and WECS is combined to get hybrid system which is delivering power to load combinable. In this the parameters of Solar are No. of series Cells 4, No. of parallel Cells 89, Standard Light Intensity 1000 W/m^2, Temperature25^o c. WT parameters:Nominal mechanical output power 250 kW,Base power of the electrical generator (VA) 250 KVA, Base Wind Speed 14 m/s. DFIG parameters: Nominal power 250 kW,frequency 50 Hz,stator resistance 0.0108 Ω,rotor resistance 0.0121Ω. Simulink block of hybrid system is shown in Fig 7, which consists of solar and wind sources.
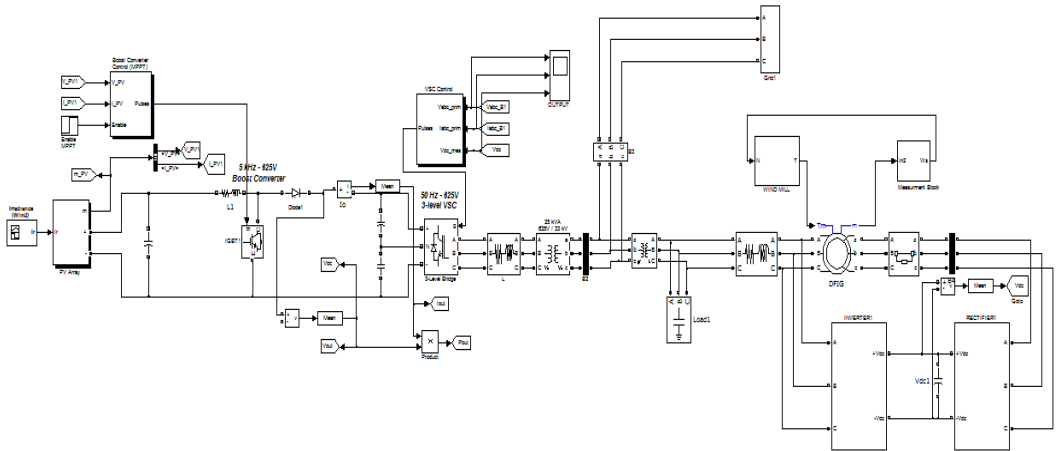

Fig. 7. Simulink block of hybrid system

11. Simulation results

The parameters of the PV panel, wind turbine and DFIG, are given in Appendix. Simulation is done on Matlab 2011b and results shown below. Generated voltage of solar PV system is not sufficient since a boost converter is used for rise of voltage. The output voltage after boosting is 625 V irrespective of variation in solar panel voltage. It is shown in Fig 8. Firing pulses of IGBT switches are generated by Incremental Conductance MPPT technique.Step input given to the solar panel i.e. 500W/m^2 up to 0.6sec after 1000W/m^2 is maintained Boost converter output maintain Constant 625V.A PWM three phase inverter is used for conversion of boosted voltage from DC to AC, as result 625 V AC per phase is obtained. Since it is obtained due to PWM inverter, it is in pulses form, not fully sinusoidal.
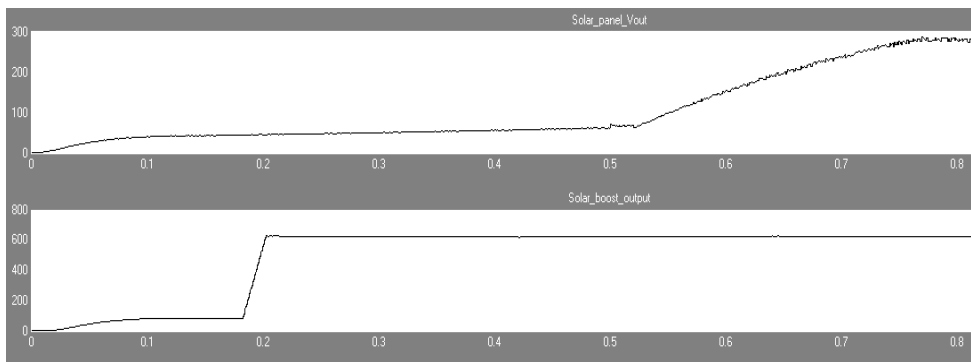

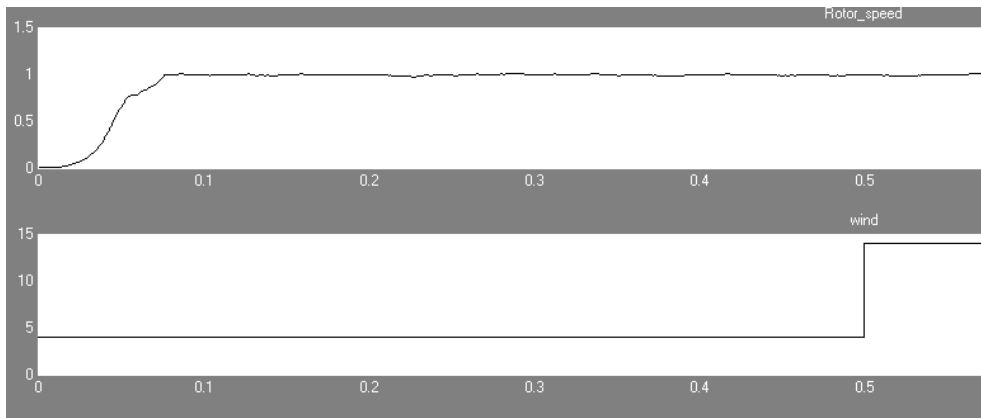Fig. 8. Solar panel output and b. Boost converter output

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Fig. 9(a)The Rotor Speed in pu and (b) Wind Speed

Simulation waveforms for a period of 0.8 sec with change in wind speed at 0.5sec i.e. up to 0.5sec 4m/s after 0.5sec 14m/s shown in Fig 9 shows the rotor speed. and Fig 10 shows DC link voltage 580 V.
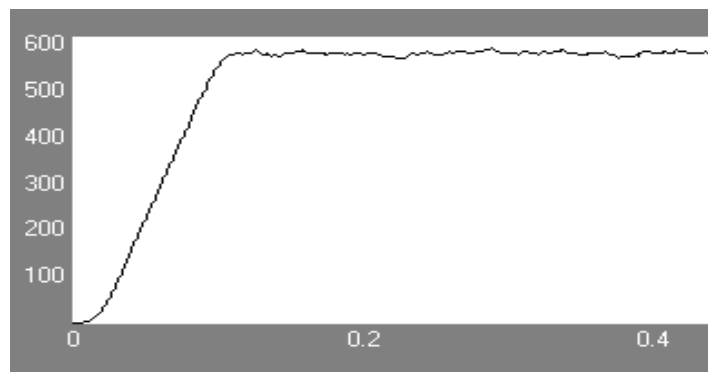

Fig. 10. DC link voltage

12. Conclusion

Using MPPT with solar panel installations has all the way advantages. The initial investment is smaller because smaller panel wattage is required. In this paper, incremental conductance MPPT technique is developed the output of the MPPT is given to the comparator to generate PWM pulses which is required for Boost converter. To raise the solar panel voltage a boost converter circuit is designed, to convert DC-AC 3-level NPC inverter is used and vector control principle is used. One more energy source DFIG based wind turbine is used, now a days DFIG are extremely used in wind farms because it supplies power at constant voltage and frequency. To maintain constant voltage and frequency need a back to back converter and controller for back to back converter is implemented. Characteristics of DFIG are studied and also control technique of DFIG have been analysed in MATLAB-SIMULINK environment.
The paper provides architecture with modelling and simulation of a hybrid energy sources. Solar and wind power are the two sources being used. Established system of solar PV and DFIG based wind is simulated in Matlab Simulink for step change condition.

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