# Grid Connected Solar and Wind Hybrid System

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## Abstract

Renewable Energy Resources are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies which are most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, which are in direct relation with the use of micro and smaller in capacity power generating units that are installed in distribution part of each power combined system or all the possible locations that loads and energy consumers are concentrated. Hybrid systems are of different states. One of the practices possible to provide these hybrids is combination of grid connected wind turbines and solar photovoltaic generators that together each could sit instead of the other one in a grid connection state when one of them cannot generate the required electricity for consumption by load properly. Moreover, Solar cells can generate the electricity required in the day while wind turbines can compensate the needs in the night by wind energy. The proposed architecture consists of solar PV and wind energy system. In solar PV system MPPT technique is applied to maximize power output, a boost converter is employed to raise DC voltage and its output is fed to a three phase PWM inverter for converting DC voltage to AC at 50Hz frequency. In wind energy conversion system Permanent Magnet Synchronous Generator (PMSG) is driven by two masse drive train based wind turbine with zero pitch angles. Simulation study of the proposed system is carried out with MATLAB Simulink and simulation results are provided.

**Keywords: PV System, PMSG, Wind System, WECS, Hybrid Solar and Wind, Photovoltaic System**

## I. INTRODUCTION

The increasing demand for conventional energy sources like coal, natural gas and oil is forcing people towards the research and development of renewable energy sources or non-conventional energy sources. Many renewable energy sources like wind, solar etc are now well developed, cost effective and largely used. These energy sources are environment friendly. Hybrid energy system is the combination of two or more renewable energy sources like wind, solar, hydro etc .These provide a clean and eco-friendly energy. These hybrid systems can be standalone or can be grid connected. The grid connected hybrid system are more reliable to deliver continuous power to the grid because if there is any shortage of power or fault in the renewable energy sources then the loads are directly connected to the grid. The hybrid power system consist of two Renewable energy sources which are solar energy and wind energy that are used as a input sources . A wind turbine converts mechanical energy into electrical energy and it produces ac output voltage and this ac output voltage is converted to dc by the help of ac to dc converter or rectifier. A PV cell converts the light energy into electrical energy and produces dc output voltage. The reliability to deliver continuous supply to load is more for grid connected hybrid wind and PV system. if there occurs any problem with the energy sources then the loads are connected to the grid.

The main objective of this paper is to model a grid connected Solar and Wind hybrid power system. In this model, outputs of these two sources are determined. The input for these two sources is solar radiation and wind speed. The modeling of both PV system and wind is done. The analysis of the output of system is made.

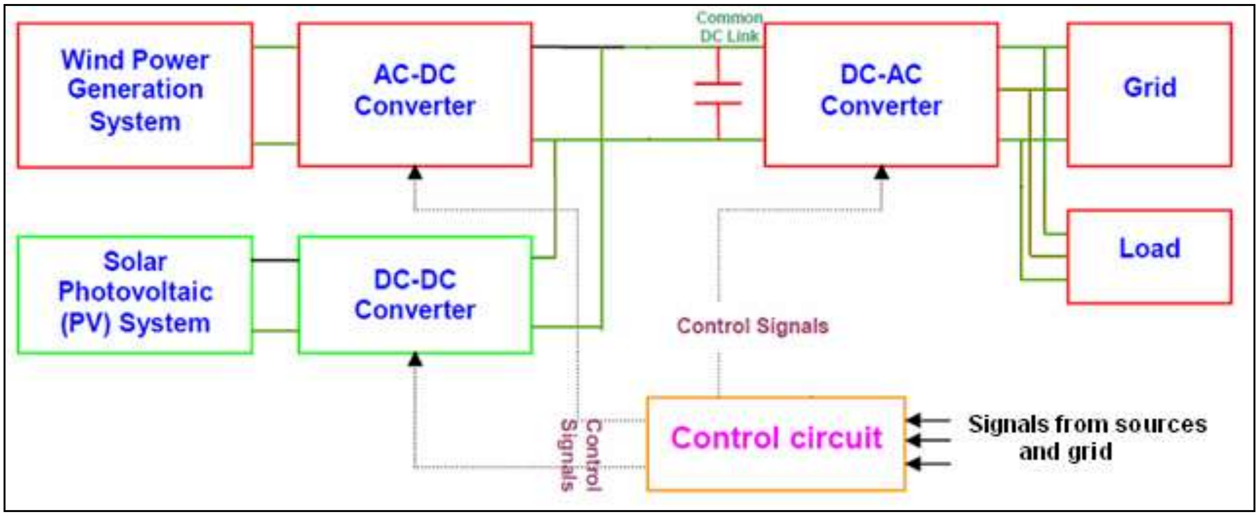

Fig. 1: Schematic diagram of proposed system.

## II. LITERATURE REVIEW

Sonam Mishra et al [1] this paper proposed architecture consists modelling and simulation of solar PV and wind energy hybrid system. In solar PV system MPPT technique is applied to maximize power output, a boost converter is employed to raise DC voltage and its output is fed to a three phase PWM inverter for converting DC voltage to AC at 50Hz frequency. In wind energy conversion system PMSG is driven by two masse drive train based wind turbine with zero pitch angles. Both systems supplying individual and combined loads of lkW.

Dr. A.K.Pandey et al [3] In This paper the modeling and simulation of a grid connected PV and Wind Hybrid Power System are described. Both the systems are connected parallel at DC link and then connected to the grid. The output of PV and wind after combining is given to the inverter. The main problems of hybrid system are involved with stability and power quality and for these problems improvement inverter's gate pulse is controlled. The harmonic analysis of grid voltage and current is done and THD is also obtained.

Md. Sifat Ferdous Chowdhury et al [4] this paper introduces the performance of hybrid power system which has a combination of solar power and wind power. PV array is extracting maximum energy from sunlight irradiation by using Maximum Power Point Tracker; it collects the power from the system and sends power to the dummy utility grid. On the other hand, depending on the velocity of the wind available, wind turbine rotates and energizes an asynchronous generator for power supply to the grid. These two separate sources are connected together for hybrid operation and synchronized appropriately for segmented power supply to the grid.

M. Lokanadham et al [5] this paper has been modelled PV array with a circuit based simulation of MPPT algorithm and duty cycle has been derived accordingly for a DC-DC boost converter to feed the dc load. The results show that the MPPT by using INC method is fast and efficient compared to conventional Hill climbing algorithm. This method requires more computation in the controller, but can track changing conditions more rapidly for long time partial shading condition (PSC) than the conventional method.

## III. PHOTOVOLTAIC SYSTEMS

### A. *PV Equivalent Electrical Circuit Model*

In the crystalline silicon PV module; the complex physics of the PV cell can be represented by the equivalent electrical circuit shown in Figure 2. For that equivalent circuit a set of equations have been derived, based on standard theory, that allow the operation of a single solar cell, to be simulated using data from manufacturers or field experiments.

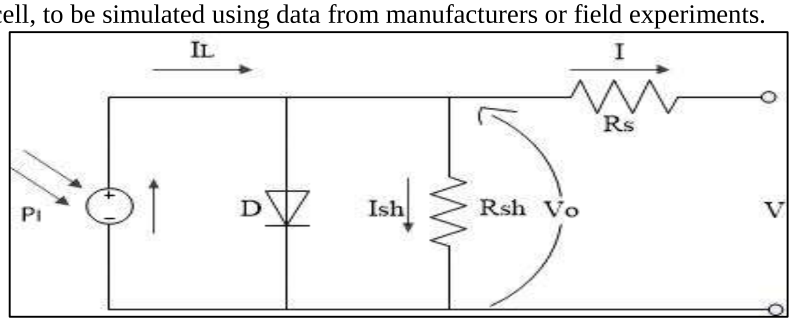

Fig. 2: Equivalent electrical circuit of PV module

 

The circuit parameters are as follows:

– The output-terminal current I equals to the light-generated current$I_L$, less the diode-current $I_d$ and the shunt-leakage current $I_{sh}$.
– The series resistance $R_s$ represents the internal resistance to the current flow, and depends on the p-n junction depth, the impurities and the contact resistance.
– The shunt resistance Rsh is inversely related with leakage current to the ground.

In an ideal PV cell, $R_s$ = 0 (no series loss), and $R_{sh}$ = ∞ (no leakage to ground). In a typical high quality one square inch silicon cell, $R_s$ = 0.05 to 0.10 ohm and $R_{sh}$ = 200 to 300 ohms. The PV conversion efficiency is sensitive to small variations in Rs, but is insensitive to variations in $R_{sh}$ Therefore, we can ignore $R_{sh}$ from the equivalent electrical circuit for our modeling.

### *B. Mathematical modeling of the PV system*

The equivalent circuit of Figure 2, the current delivered to the external load equals the current IL generated by the illumination, less the diode current Id and the ground-shunt current$I_{sh}$. The load current is given by the expression:

$$I = I_L - I_d - \frac{V_0}{R_{sh}} \quad \text{……………………..} (1)$$

The cell could be represented by a voltage-current Eq as follow

$$V = V_0 - R_S I$$

Where:

$V_0$ = $V_{sh}$= voltage on the diode and the shunt resistance
$I_d$ = diode Current (A).
V = cell output voltage (V).
I = load (cell) output current (A).
$I_L$ = Photocurrent (A).
$I_0$= Reverse diode saturation current (A).

The two most important parameters widely used for describing the cell electrical performance are the open-circuit voltage $V_{oc}$ and the short-circuit current$I_{scc}$. The short-circuit current is measured by shorting the output terminals, and measuring the terminal current under full illumination. The maximum photo-voltage is produced under the open-circuit voltage. The open circuit voltage $V_{oc}$ of the cell is obtained when the load current is zero, i.e., when I = 0.

### *C. Mathematical modeling of Environmental factors*

The general equation describing the (I-V) characteristics of the PV cell is obtained from Eq.1 by ignoring the last term of the shunt resistance, and using the famous formula used for the diode current, as follows:

$$I = I_L - I_O(e^{\frac{q(V+IRs)}{nKTr}} - 1)$$

Where:

q = electron charge = $1.6 \times 10^{-19}$ Coulombs.
n = ideality factor = 1 to 2.
K = Boltzmann constant = $1.38 \times 10^{-23}$Joule/K
$T_r$ = rated cell temperature in Kelvin.
$R_s$ = cell series resistance (ohm).

### *D. Effect of Variation in Cell Temperature [4]*

The value of the saturation current $I_o$ at different operating temperatures is calculated as follow:

$$I_o = I_{o_{(Tr)}} * (T/Tr)^3 * e^{\frac{qVg}{nk}*\{\frac{1}{Tr}-\frac{1}{T}\}}$$

$$I_{o_{(Tr)}} = I_{SC_{(Tr)}} / \left[e^{\frac{qV_{oc_{(Tr)}}}{nKT}} - 1\right]$$

Where:

Vg = The band gap voltage
$V_{oc_{(Tr)}}$= Open Circuit voltage at rated operating conditions.
$I_{SC_{(Tr)}}$ = Short circuit current at rated operating conditions.
T is operating temperature of the cell (K)

### *E. Effect of Solar Radiation Variation [4]*

The photocurrent $I_L$(A)is directly proportional to solar radiation level G (W/m2), as follow:

$$I_L = I_{L_{(Tr)}}(1 + \alpha_{I_{SC}}(T - Tr))$$

$$I_{L_{(Tr)}} = G * I_{SC_{(Tr,nom)}}/Gr$$

$$\alpha_{I_{SC}} = d_{I_{SC}}/dT$$

Where, $\alpha_{Isc}$ = the short circuit temperature coefficient (A/sec).

 

G is operating solar radiation level
$G_r$ Is rated solar radiation level

Now for an array containing NS cells in series and such NP strings in parallel. We can modify the diode current equations of the cell as presented below:

$$I_d = I_O(e^{\frac{q(V+IRs)}{nKTrNs}} - 1)$$
$$I_o = I_{o(Tr)} * (T/Tr)^3 * e^{\frac{qVg}{nk}*\{\frac{1}{Tr}-\frac{1}{T}\}}$$
$$I_{o(Tr)} = I_{SC(Tr)}/[e^{\frac{qV_{oc(Tr)}}{nKT}} - 1]$$

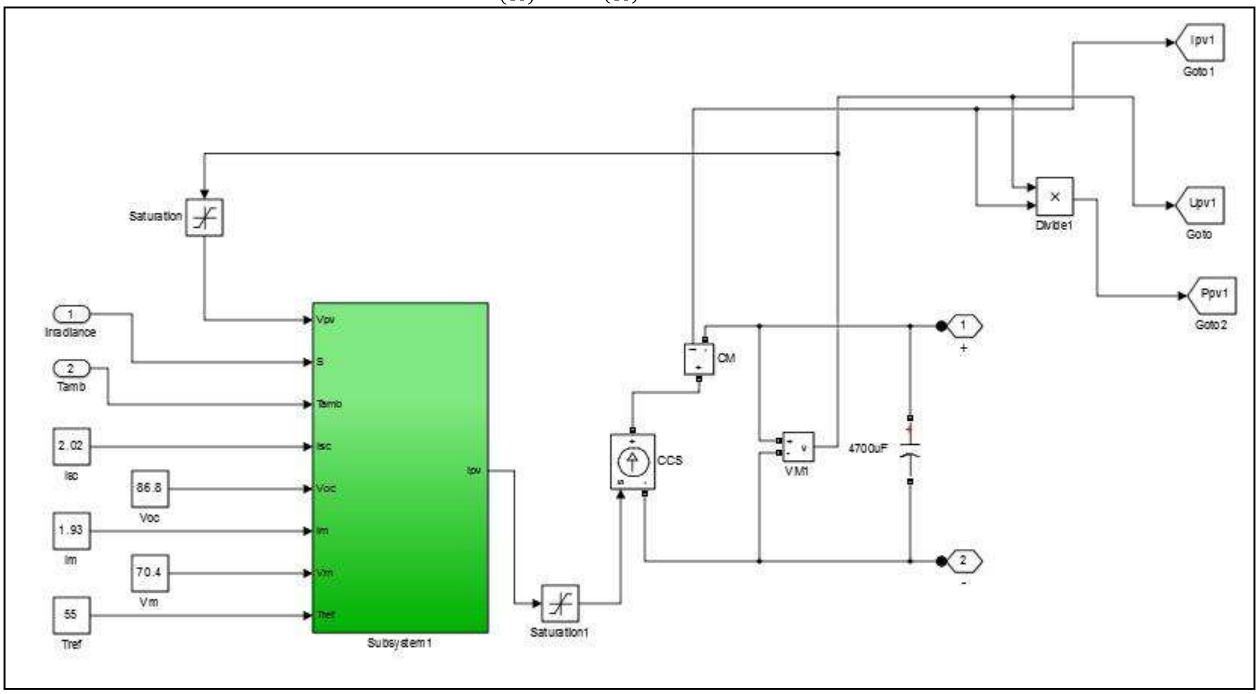


Fig. 3: Simulation model of PV System

## IV. WIND TURBINE SYSTEM

Wind turbine is applied to convert the wind Energy to mechanical torque. The mechanical torque of turbine can be calculated from mechanical power at the turbine extracted from wind power. This fact of the wind speed after the turbine isn't zero. Then, the power coefficient of the turbine ( $C_p$ ) is used. The power coefficient is function of pitch angle ( $\beta$ ) and tip speed ( $\lambda$ ), pitch angle is angle of turbine blade whereas tip speed is the ratio of rotational speed and wind speed. The power coefficient maximum of ($C_p$) is known as the limit of Betz.

The power coefficient is given by

$$C_P(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - c_3\beta - c_4\right)e^{-\frac{c_5}{\lambda_i}} + c_6\lambda$$
$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

The power coefficient is given by

$$c_p = \frac{p_m}{p_w} \quad ; \; c_p < 1$$
$$p_m = c_p(\lambda,\beta)\frac{\rho S}{2}v_w^3$$

Where
$P_m$ = the mechanical output power of the turbine
$C_p$ = the performance coefficient of the turbine
$\rho$ = the air density
S = the turbine swept area
$V_w$ = the wind speed
$K_p$ = gain power
$\lambda$ = the tip speed ratio

β = the blade pitch angle
The mechanical torque is given by

$$T_m = \frac{P_m}{w}$$

The WECS is presented with two-mass drive train model. The mathematical model are given by [12]

$$2H_t \frac{dw_t}{dt} = T_m - T_s$$

$$\frac{1}{W_{ebs}} \frac{d\theta_{sta}}{dt} = w_t - w_r$$

$$T_s = K_{ss}\theta_{sta} + D_t \frac{d\theta_{sta}}{dt}$$

Where
$H_t$ = the inertia constant of the turbine
$\theta_{sta}$ = the shaft twist angle
$w_t$ = the angular speed of the wind turbine
$w_r$= the rotor speed of generator
$w_{ebs}$ = the electrical base speed
$T_s$ = Shaft torque
$K_{ss}$ = the shaft stiffness
$D_t$ = the damping coefficient

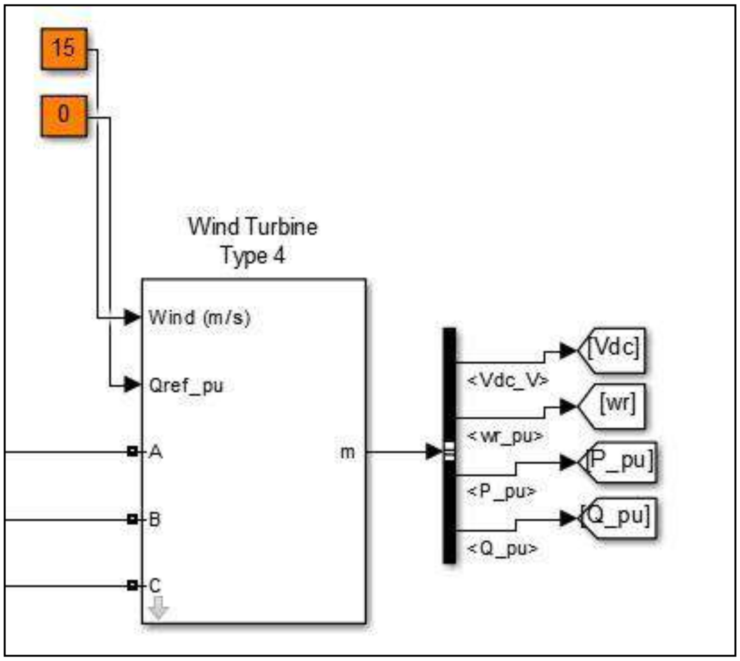


Fig. 4: Simulation model of Wind Turbine

### A. *Modelling Of Wind-PV Hybrid System in MATLAB / SIMULINK:*

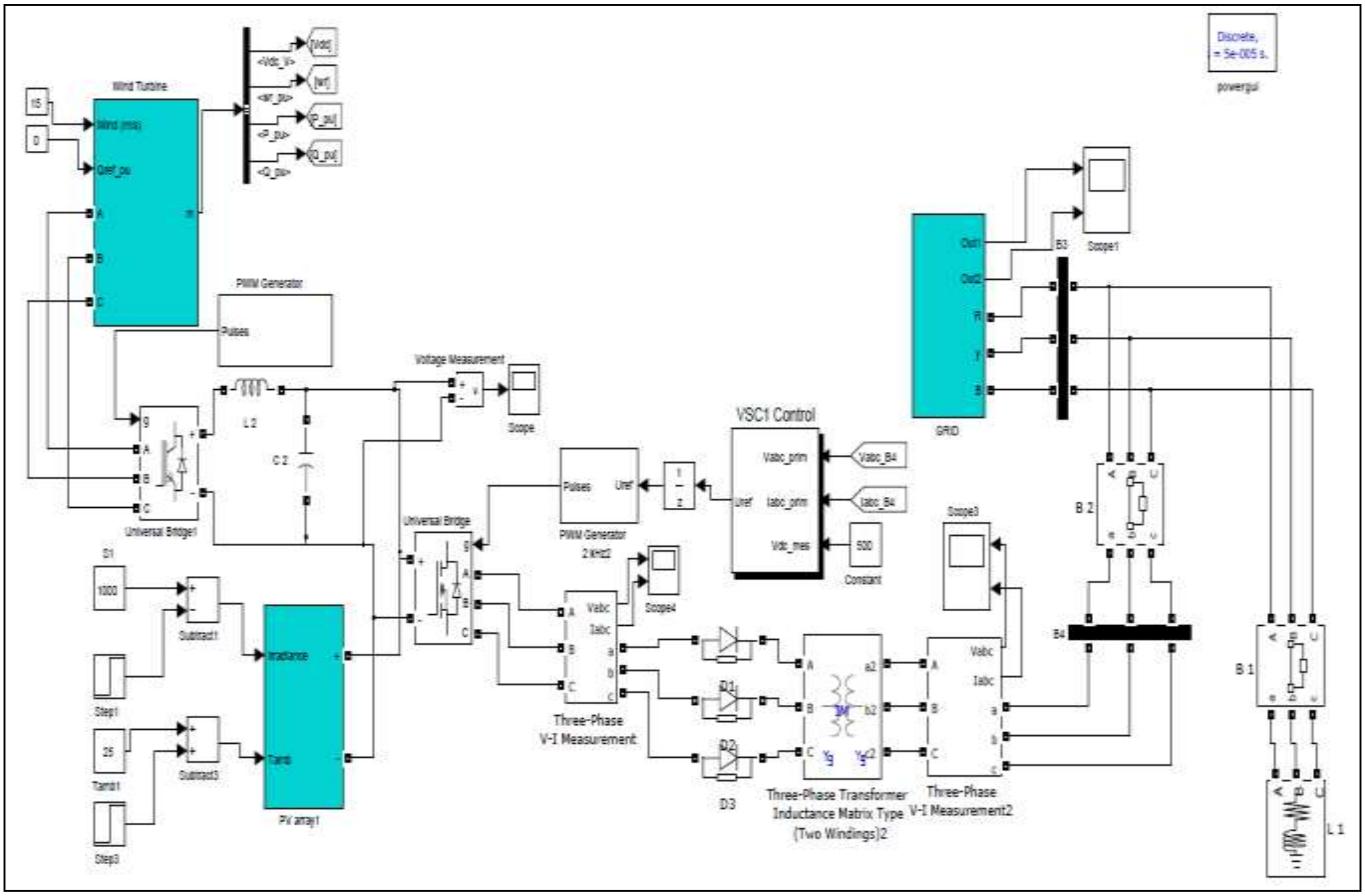


Fig. 5: Simulation model of Wind-PV Hybrid Power System

## V. SIMULATION RESULT

For the simulation, solar irradiance and wind speed are used. The data is the input of PV and Wind energy system. The waveforms of the PV and Wind energy generation system are shown and also the waveform of grid voltage and current is obtained.

Table – 1
Parameters of PV System

| *Parameter* | *Value* |
|---|---|
| *Voltage at $P_{max}$ ($V_{mp}$)* | *70.4 V* |
| *Current at $P_{max}$ ($I_{mp}$)* | *1.93 A* |
| *Short circuit current ($I_{sc}$)* | *2.02 A* |
| *Open circuit voltage ($V_{oc}$)* | *86.8 V* |
| *Rs* | *0.55 Ω* |
| *Ki* | *0.00288 A/K* |
| *Ns* | *36* |

Table – 2
Parameters of Wind Turbine

| *Parameter* | *Value* |
|---|---|
| *Rated Power* | *20 KW* |
| *Rated Wind Speed* | *15 m/s* |
| *Blade Radius* | *2.5 m* |
| *Blade Pitch Angle* | *0 degree* |
| *Air Density* | *1.225 kg/m3* |
| *Rated Rotor Speed* | *21.09 rad/s* |

 

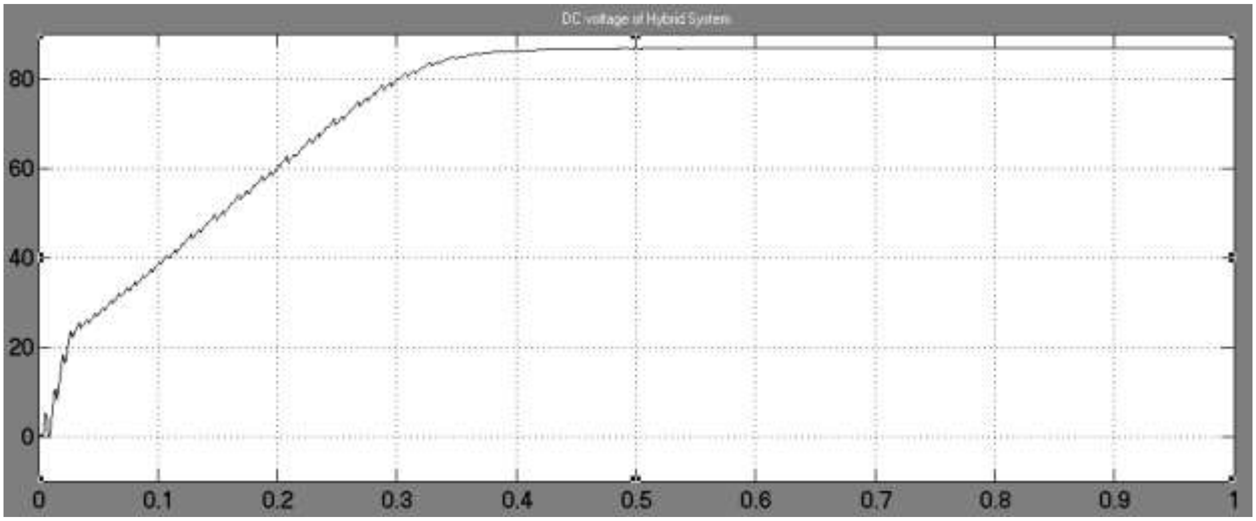


Fig. 6: DC Voltage of Hybrid System

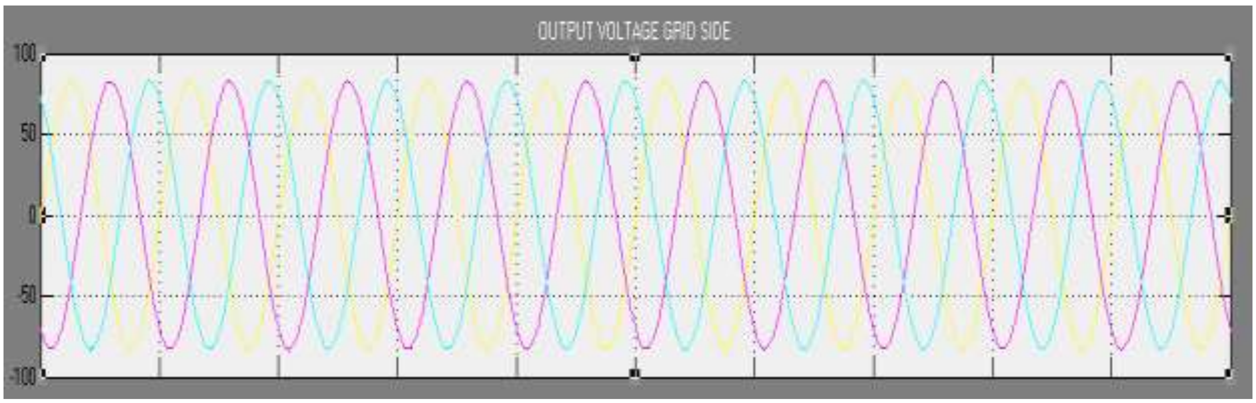


Fig. 7: Waveform of Output Voltage at grid side

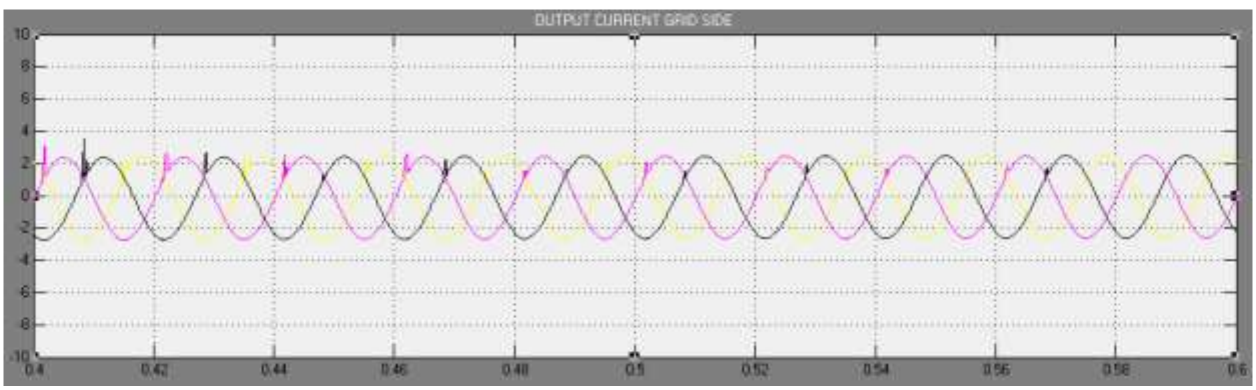


Fig. 8: Waveform of Output Current at grid side

## VI. CONCLUSION

This paper presented the modeling, simulation and Control of a grid connected PV and Wind Hybrid Power System. The system is simulated in Matlab/Simulink environment. It is observed that the extraction of the maximum power from SPV array is obtained using MPPT system. The INC MPPT algorithm has been implemented. In Wind Energy Conversion system Permanent magnet synchronous generator based wind turbine used. The PV output and the wind output after converting to dc by the help of rectifier is given to the inverter and then the combination of PV and Wind is given to the grid.

 

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## REFERENCES


[1] Sonam Mishra, Manju Gupta, AartiGarg, Rahul Goel&Vimal Kumar Mishra "Modeling and Simulation of Solar Photo-Voltaic and PMSG Based Wind Hybrid System" lEEE Students Conference on Electrical, Electronics and Computer Science-2014.

[2] S.Saib, A.Gherbi "Simulation and Control of hybrid renewable energy system connected to the grid" IEEE published in Energy (IYCE), 2015 5th International Youth Conference on May-2015

[3] Dr. A.K.Pandey & Aditi "Performance Analysis of grid connected PV Wind Hybrid Power System" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11 @ Research India Publications.

[4] Md. SifatFerdousChowdhury and Mohammad Abdul Mannan "Simulating Solar and Wind Based Hybrid Systems Synchronized and Segmented for Grid Connectivity" International Journal Of Multidisciplinary Sciences And Engineering, VOL. 5, NO. 8, AUGUST 2014.

[5] M.Lokanadham and K.VijayaBhaskar, "Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic System" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 2, page(s): 1420-1424,Mar-Apr2012.

[6] Kamal Keshavani , Jigar Joshi , VishrutTrivedi and MiteshBhavsar "Modelling and Simulation of Photovoltaic Array Using Matlab/Simulink" International Journal of Engineering Development and Research © 2014 IJEDR, Volume 2, Issue 4, ISSN: 2321-9939

[7] Tarak Salmi, MounirBouzguenda,,Adel Gastli, and Ahmed Masmoudi "MATLAB/Simulink based Modelling of Solar Photovoltaic Cell" INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH, TarakSalmi et al., Vol.2, No.2, 2012

[8] Saeedjahdi and Loi Lei Lai, Energy Systems Group Daniel Nankoo "Grid Integration of Wind-Solar Hybrid Renewables Using AC/DC Converters as DG Power Sources" IEEE 2011

[9] ParitaDalwadi, V. Shrinet, C R Mehta, and Pankit Shah "Optimization of Solar-Wind Hybrid System for Distributed Generation" INTERNATIONAL CONFERENCE ON CURRENT TRENDS IN TECHNOLOGY, Conference Record of the 2011 IEEE.

[10] Magdi M El-Saadawi,Ahemed E. Hassan,Khaled M. Abp-Al-Ez,A "Proposed Dynamic Model of Photovoltaic-DG System", Mansoura University, Egypt.

[11] Sanjiba Kumar Bisoyi, R.K.Jarial and R.A.Gupta " Modeling and Analysis of Variable Speed wind Turbine equipped with PMSG" International Journal of Current Engineering and Technology, E-ISSN 2277-4106, P-ISSN 2347-5161.

[12] K.Prechanon "Mathematical Model of the PMSG based on Wind Energy Conversion System" International Research Journal of Innovative Engineering, Volume1, Issue 3 of March 2015, ISSN: 2395-0560.