

Implementation of a Wind/PV Hybrid System using MATLAB/Simulink

Anjali Rana¹, Mohammad Ilyas²M. Tech Student [Power Systems], Dept. of EEE, Al-Flah University, Faridabad, Haryana, India¹Assistant Professor, Dept. of EEE, Al-Flah University, Faridabad, Haryana, India²

ABSTRACT: Due to development in renewable energy technologies and continued rise in prices of petroleum products hybrid renewable energy systems are gaining more importance for supplying the power to meet the today's increasing energy demands either as a stand-alone system or as a grid connected system. In this paper a model of grid connected hybrid system consists of wind and solar (photovoltaic) system is studied and implemented in Simulink. The proposed system consists of a wind turbine, a PV solar cell array, boost converter, and an inverter to convert DC to AC of grid frequency. A relative study of hybrid model solar/wind system has been made. This Paper illustrates wind and solar hybrid system for supplying electricity to the power grid.

KEYWORDS: Hybrid, Wind turbine, PV cell, Power grid, Boost converter.

I. INTRODUCTION

In the last few years, because of high depletion of conventional energy resources and environment concerns, the renewable energy resources are becoming more important all over the world. Among different renewable energy sources, wind and solar energy sources are most promising. Since the oil crisis of the early 1970s, the utilization of solar and wind power has become increasingly noteworthy, popular and cost-effective. But the main disadvantage of solar and wind energy system is that it depends on seasonal variation and it is unpredictable in nature. As both wind and solar energy sources are not consistent and non-stable in nature. A hybrid system of wind and PV power sources provides a stable form of power generation. Hybrid energy systems are cost effective energy solutions with high reliability and power quality. Individual photovoltaic (PV) or wind energy system, do not generate utilizable energy for a large portion of time during the year. This is because of dependency on variable sunshine hours in PV system and on relatively high cut-in wind speeds. In this paper individual modeling of PV and wind energy system is done and studied in Matlab/Simulink software. A Hybrid model of PV and Wind system is also implemented and studied.

II. MATHEMATICAL MODELING OF SOLAR PV CELL

Solar (PV) systems capture the sunlight and directly convert it into electricity. Photovoltaic (PV) cell is the basic element of a PV system. A photovoltaic cell is a semiconductor diode whose p-n junction is open to the light. When sunlight strikes the solar cell junction, free electrons and holes are generated and a current is delivered to the load when it is short circuited. A grouping of PV cells forms a solar panel. To obtain large output voltage solar panels are formed by connecting PV cells in series and to achieve large output current cells are connected in parallel. Fig.1 shows the equivalent circuit of a PV cell.

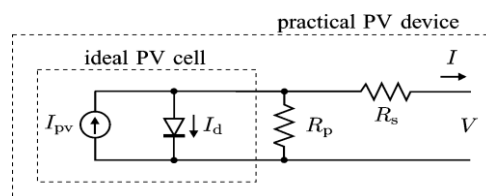


Fig. 1 Equivalent circuit of a PV cell

The basic equation that describes the I-V characteristics of the PV cell is given as:



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

$$I = I_{pv,cell} - I_{o,cell} \left[\exp\left(\frac{qV}{akT}\right) - 1 \right] \quad (1)$$

Where $I_{pv, cell}$ = incident light current (which is directly proportional to the sun radiation),
 I_d = Shockley diode equation
 $I_{o, cell}$ = reverse saturation or leakage current of the diode
 q = electron charge ($1.60217646 \times 10^{-19}$ C)
 k = Boltzmann constant ($1.3806503 \times 10^{-23}$ J/K)
 T = temperature of the p-n junction
 a = diode ideality constant

The equation (1) of PV cell does not show the I-V characteristics of a practical PV array. To observe PV array characteristics inclusion of some additional parameters to the equation (1) is necessary. Hence the equation is represented as:

$$I = I_{pv} - I_o \left[\exp\left(\frac{V + R_s I}{V_t a}\right) - 1 \right] - \frac{V + R_s I}{R_p} \quad (2)$$

In this equation V_t is the thermal voltage and R_s & R_p are the equivalent series and parallel resistances. Equation (2) describes the single diode model shown in Fig.1.

The incident light current of PV cell depends on solar irradiation and is greatly affected by the temperature can be expressed as:

$$I_{pv} = (I_{pv,n} + KI\Delta T) \frac{G}{G_n} \quad (3)$$

Where $I_{pv, n}$ = incident light current at nominal conditions (25^0 C and $1000W/m^2$)
 $\Delta T = T - T_n$ (difference between actual and nominal temp)
 G and G_n is the actual and nominal irradiation respectively

The reverse saturation current I_o also affects by temperature which is represented as:

$$I_o = I_{o,n} \left(\frac{T_n}{T}\right)^3 \exp\left[\frac{qE_g}{ak} \left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \quad (4)$$

Where E_g = band gap energy of the semiconductor
 $I_{o, n}$ = nominal saturation current

Table 1 shows the electrical parameters that are considered for designing the PV array with ambient temperature (T_{amb}) of 28^0C and solar insolation of $900w/m^2$.

Table.1 Electrical parameters for PV array

S. No.	Parameters	Values
1.	Voltage at Maximum power	75.4 V
2.	Current at Maximum power	2.93 A
3.	Open circuit voltage	96.8 V
4.	Short circuit current	3.02 A
5.	Reference Temperature	60^0C

III.STEP BY STEP SIMULINK MODELING OF SOLAR PV MODULE

PV cell converts the solar radiation directly into electricity with both I-V and P-V output characteristics. Based on the above mathematical equations simulink modeling of PV module is done in following steps:

A. STEP I

A subsystem is shown in fig. 2. This model calculates the short circuit current (I_{sc}) with inputs of Solar Insolation/irradiance (S) = $900w/m^2$, Ambient temperature (T_{amb}) = 28^0C , short circuit current (I_{sc}) = 3.02A, and reference temperature (T_{ref}) = 60^0C .

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

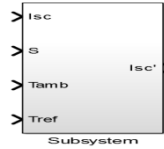


Fig. 2 Subsystem to calculate I_{sc}

The below figure shows the circuit of the above subsystem.

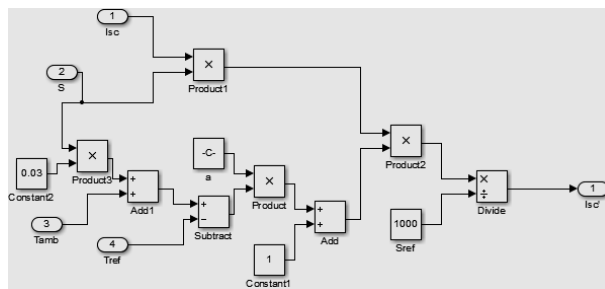


Fig. 3 Circuit of subsystem to calculate I_{sc}

B. STEP II

A subsystem is shown in fig. 4. This model calculates the open circuit voltage (V_{oc}) with inputs of $S = 900\text{w/m}^2$, $T_{amb}=28^\circ\text{C}$, $V_{oc} = 2.93\text{A}$, $T_{ref} = 60^\circ\text{C}$.

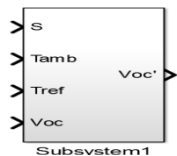


Fig. 4 Subsystem 1 to calculate V_{oc}

The below figure shows the circuit of the above subsystem.

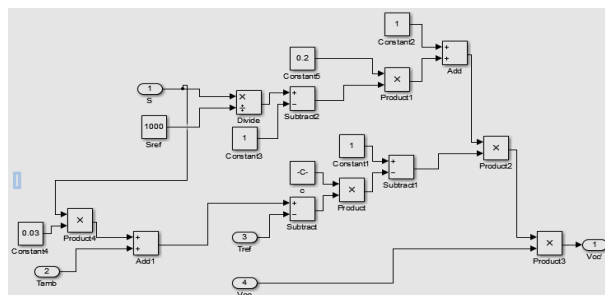


Fig. 5 Circuit of subsystem 1 to calculate V_{oc}

C. STEP III

A subsystem to calculate the current at Maximum power (I_m) with inputs of $S = 900\text{w/m}^2$, $T_{amb}=28^\circ\text{C}$, $I_m = 2.93\text{A}$, $T_{ref} = 60^\circ\text{C}$ is shown in fig.6.

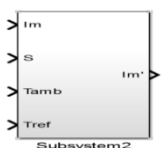


Fig. 6 subsystem 2 to calculate I_m

The below figure shows the circuit of the above subsystem.

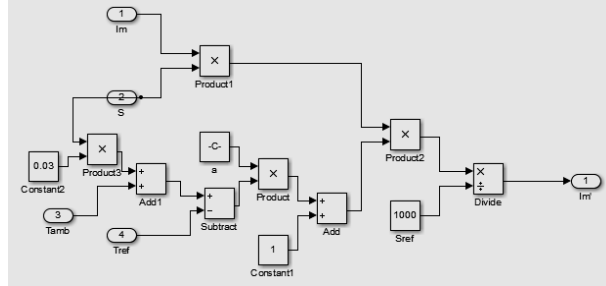


Fig.7 Circuit of subsystem 2 to calculate I_m

D. STEP IV

A subsystem to calculate the Voltage at Maximum power (V_m') with inputs of $S = 900\text{w/m}^2$, $T_{\text{amb}}=28^\circ\text{C}$, $V_m = 75.4\text{V}$, $T_{\text{ref}} = 60^\circ\text{C}$ is shown in fig.8.

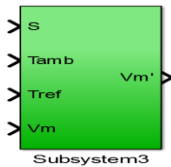


Fig. 8 Subsystem 3 to calculate V_m'

The below figure shows the circuit of the above subsystem.

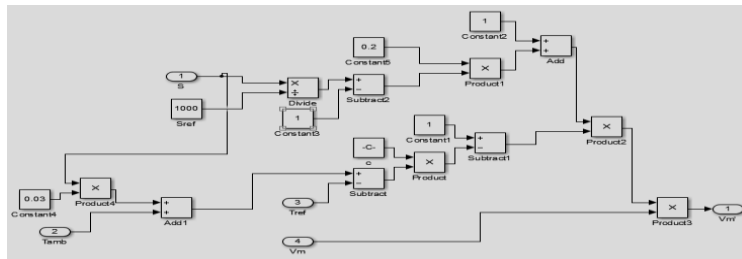


Fig. 9 Circuit of subsystem 3 to calculate V_m'

E. STEP V

A complete connected model of subsystems is shown in fig.10. In this figure all subsystems are interconnected to calculate the incident light current I_{pv} .

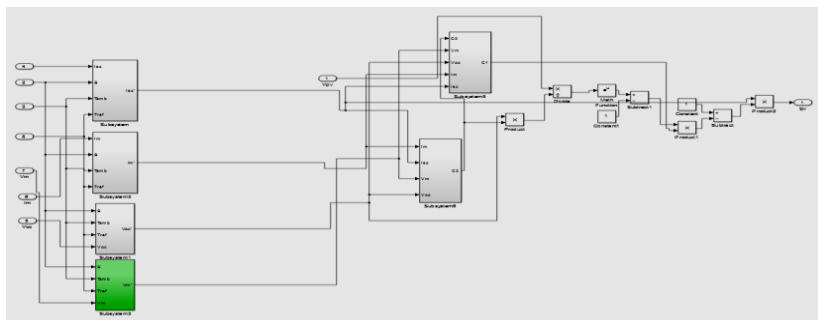


Fig.10 Interconnection of all subsystems

In fig. 11, it shows the complete model of PV array, we get after connecting all the subsystems simulated above to calculate the photo current (I_{pv}).

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

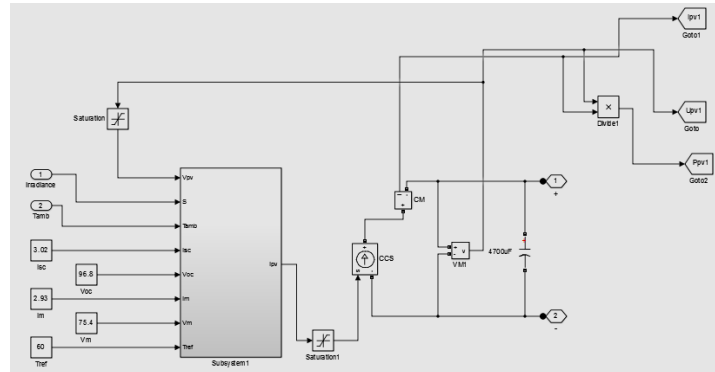


Fig. 11 Complete model of a PV array

IV.MODELLING OF WIND TURBINE

Wind energy is an environment friendly and endless source. Therefore, a wind energy generation system may be one of the promising sources of alternative energy for the future demand. Wind turbines convert the kinetic energy of wind into mechanical energy. The magnitude of this converted mechanical energy depends on the air density and the wind velocity. The wind power (P_m) that is developed by the turbine is given by the equation:

$$P_m = \frac{1}{2} C_p(\lambda, \beta) \rho A w^3 \quad (5)$$

Where C_p = performance coefficient of turbine

ρ = air density (kg/m^3)

A = area of turbine blades (m^2)

w = wind velocity (m/sec)

λ = tip speed ratio of the rotor blade tip speed to wind speed

β = blade pitch angle (deg)

The coefficient C_p is the fraction of kinetic energy which is converted by wind turbine into mechanical energy. It is related to the tip speed ratio (λ).

Wind turbine output torque (T_m) can be calculated using equation:

$$T_m = \frac{1}{2} \rho A C_p \frac{w}{\lambda} \quad (6)$$

Fig.12 shows the ideal power curve of the wind turbine showing different operating regions with three different wind speeds i.e. cut-in wind speed, rated wind speed and cut-out wind speed.

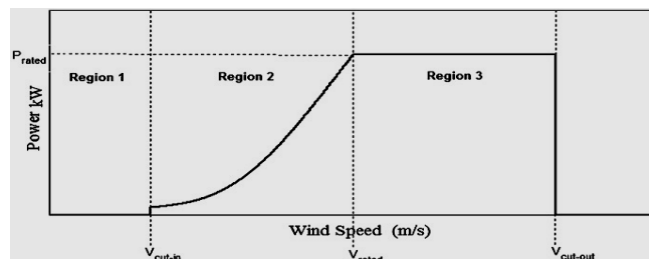


Fig. 12 Ideal power curve of wind turbine

Using above equations a simulink model is implemented as shown in fig. 13.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

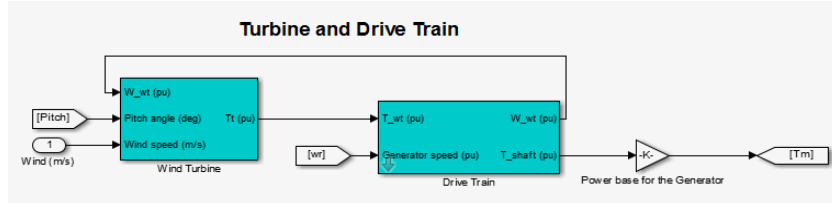


Fig. 13 Simulink model of wind turbine

This wind turbine is connected to a three phase synchronous generator which converts this mechanical power into electrical power. A single turbine is used in this work.

IV. MODELING OF HYBRID PV/WIND SYSTEM

A grouping of Wind and PV energy system into a hybrid generation system may increase their efficiency by increasing their overall energy output, by reducing energy storage requirement. This makes system less costly and more reliable as compared to individual energy system.

A hybrid system of wind and PV connected to grid is simulated. It consists of a three phase converter with PWM generator and voltage source converter which convert DC to AC of grid frequency. A simulink model of hybrid system is shown in fig. 14.

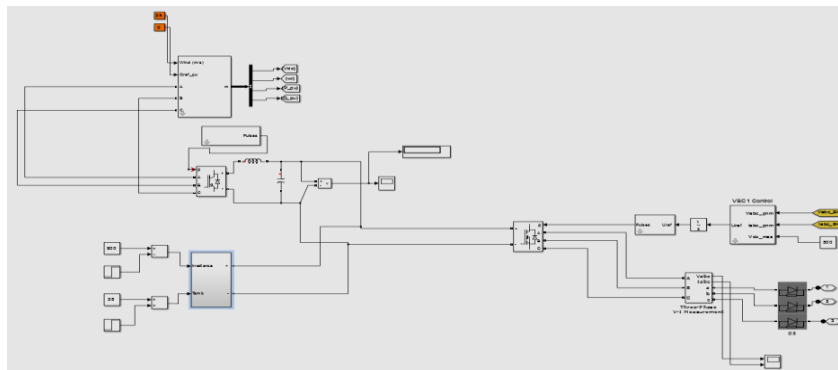


Fig. 14 Simulink model of wind/PV hybrid system

A complete simulink model of grid connected Wind/PV hybrid system is shown in figure given below.

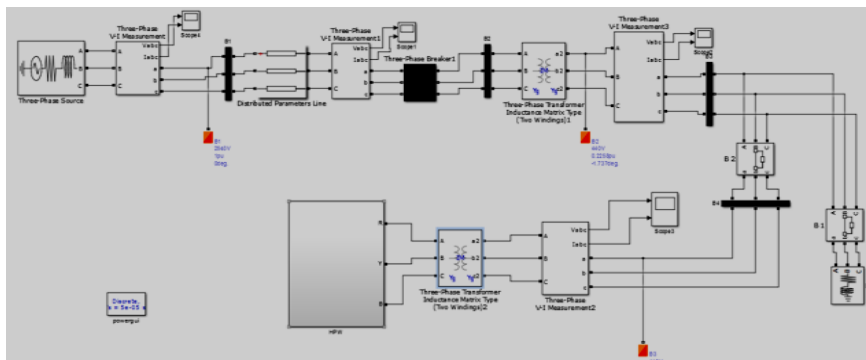


Fig. 15 Complete simulink model of grid connected wind/PV hybrid system

V.RESULT AND DISCUSSION

Different waveforms shown below are the output waveforms of implemented simulation model. These are the simulation results we obtained. In fig. 16, a DC output voltage waveform of simulated wind energy system is shown.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

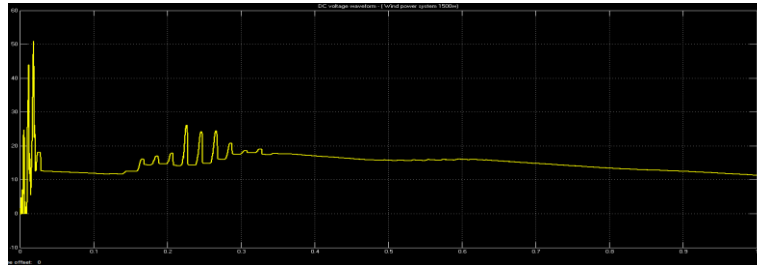


Fig.16 DC output voltage of wind system

The below figure is the waveform of DC output voltage of simulated PV energy system.

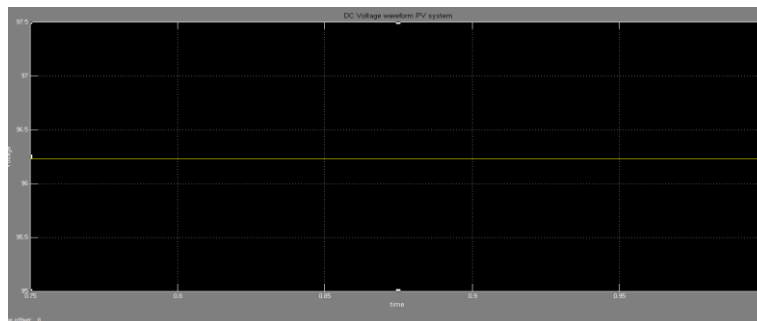


Fig.17 DC output voltage of PV system

By combining the PV and Wind energy system, a hybrid energy system has been simulated. This simulated hybrid model generates a DC voltage. The below figure shows the waveform of DC output voltage of simulated wind/PV hybrid system.

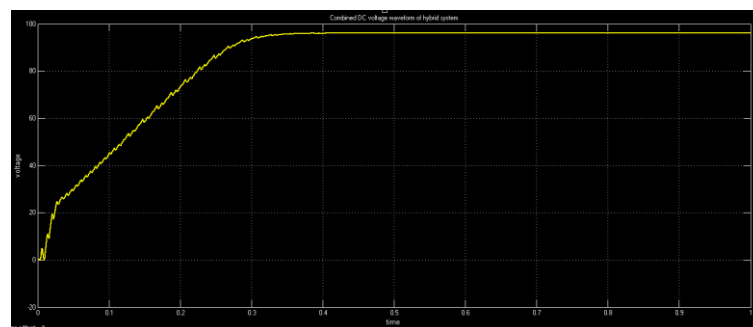


Fig. 18 DC output voltage of Wind/PV hybrid system

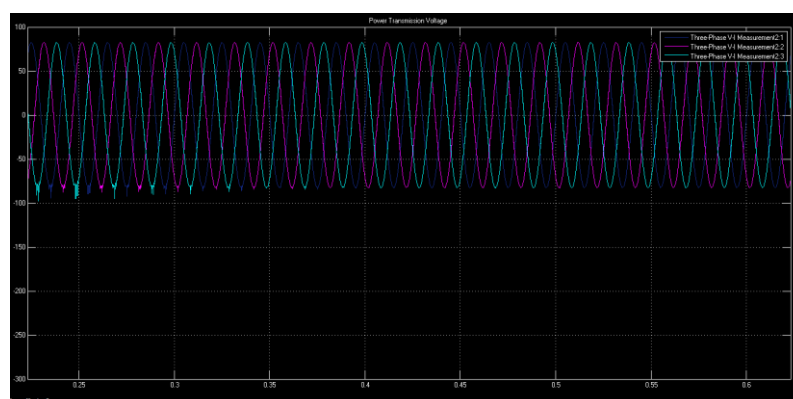


Fig. 19 Total AC output voltage of grid connected Wind/PV hybrid system



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

The DC output voltage of Wind/PV hybrid system is converted into AC which is supplied to the grid. Fig.19 shows the AC output voltage waveform. This waveform is the generated output voltage of the simulated Wind/PV hybrid energy system that is supplied to the grid at its frequency.

VI.CONCLUSION

Individual modelling and simulation study of Wind and PV system has been carried out in Matlab/simulink. Then a hybrid model has been simulated by combining these energy resources with the help of converter and voltage regulator. The simulation result of implemented hybrid system shows the generated output voltages which can be supplied to the grid. This hybrid system is more reliable as compared to single energy system.

REFERENCES

- [1] M.K. Deshmukh, S.S Deshmukh, "Modeling of hybrid renewable energy systems," Renewable & Sustainable energy reviews, pp. 235-249, 12 (2008).
- [2] M.A. Elhadiadly, "Performance evaluation of hybrid (wind/solar/diesel) power systems," Renewable energy, pp.401-413, 26 (2002).
- [3] Juan Manuel, Carrasco, Jan T. Bialasiewicz, Ramon C.Portillo Guisado, Jose Ignacio leon, "Power electronic systems for the grid integration of renewable energy resources: A survey," IEEE transactions on Industrial electronics, vol. 53, No. 4, Aug 2006.
- [4] Marcelo Gradella Villalva, Jonas Rafael Gazoli, and Ernesto Ruppert Filho, "Comprehensive Approach to Modeling and simulation of PV arrays," IEEE Transactions on Power Electronics, Vol. 24, No. 5, pp. 1198-1207, May 2009.
- [5] Mohamed A. Eltawil, Zhengming Zhao, "Grid-connected photovoltaic power systems: Technical and potential problems—A review," Renewable and Sustainable Energy Reviews, pp. 112–129, 14 (2010).
- [6] K. Shivarama Krishna, B. Murali Mohan, and Dr. M. Padma Lalitha, "Dynamic modeling & control of grid connected hybrid wind/PV generation system," IJERD, vol.10, Issue 5, pp. 01-12, May 2014.
- [7] Abdullah M.A., Yatim A.H.M., Tan C.W., Saidur R., "A review of maximum power point tracking algorithms for wind energy systems," Renewable and Sustainable Energy Reviews, pp.3220– 3227, 16 (2012).
- [8] Md. Aminul Islam, Adel Merabet, Rachid Beguenane, Hussein Ibrahim, "Power Management Strategy for Solar-Wind-Diesel standalone Hybrid Energy Systems," International Journal of Electrical, Computer, Electronics and Communication Engineering , Vol.8, issue 6, 2014.
- [9] Boucetta. Abdallah, Labeled. Djamel, "Modeling and Control of a Wind/PV Hybrid System Grid-connected," International Journal of Scientific & Engineering Research, Volume 4, Issue 8, August 2013.

BIOGRAPHY



Anjali Rana was born on 28th June 1989 in Delhi, India. She received the graduation degree in Electrical and Electronics Engineering in 2011, from UPTU Lucknow. Currently she is pursuing Master's in Power Systems from MDU Haryana. Her research interests include power generation using renewable energy resources and power quality.



MOHD. ILYAS was born on 2nd April 1976. He is an associate professor in department of electrical & electronics with Al-Falah University Faridabad, Haryana. He received his B.Tech in electrical engineering & M.Tech in electrical power system & management from Jamia Millia Islamia, New Delhi. Now he is pursuing PhD. from MD University, Rohtak. He has more than 14 years experience in teaching. He taught various subjects such as Power Electronics, Electrical measurement & Measuring Instrument, Electric Power Generation etc. He has published more than 15 papers in National & International Journals. He attended many national and international Seminars and conferences. He has guided number of B.Tech and M.Tech projects in his teaching career