International Conference on Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humanity (CIPECH14) 28 & 29 November 2014

Analysis of Grid-Tied Hybrid Wind PV Generation System

Pratiksha Gupta
Department of Electrical Engineering
Krishna Institute of Engg. & Technology
Ghaziabad

Surendra Kumar Tripathi
Department of Electrical Engineering
Krishna Institute of Engg. & Technology
Ghaziabad

Abstract— **The Hybrid power system provides an economical and sustainable power to the grid. Photovoltaic and wind energy sources are being increasingly recognized as cost effective generation sources in isolated power system. In grid-tied system, the wind turbine or the PV generation works with the grid which affects the power quality of the system. By using the AC bus architecture, power electronic component are less required which improves the controlling capability of the system. The analysis of the simulated results demonstrates the smooth operation of proposed system in a hybrid network.**

Keywords—wind energy, WECS, DFIG, photovoltaic, Wind Turbine Generator, Power Grid

I. INTRODUCTION

Environmentally friendly energy is the energy which originates from natural methods such as sunlight, the wind, rainfall, tides and also geothermal warmth. These methods are renewable which can be obviously replenished. Consequently, for all useful requirements, these types of methods can be viewed as being limitless. [1]

Photovoltaic and also the wind is definitely an irregular energy sources because it may differ after a while, nor generally meet load requirements at all times. Among these varieties of renewable energy, the wind may be the more affected resource compared to photovoltaic due to its variability. In the same way, the particular photovoltaic system in addition depends upon the next weather problems and may operate throughout day-time. Those two unpredictable energy sources standalone system will probably develop fluctuated end result energy therefore cannot assure the minimum level of power continuity required with the load [2].

A hybrid system is composed of two or more renewable energy resources with appropriate energy conversion technology connected together to feed power to local or grid. The hybrid power system exhibit larger reliability and also less expensive generation than compared to just one energy source[3]. On this project, Solar system is usually combining having turbine system to create some sort of alternative energy a hybrid of both system. Because output energy of these renewable energy is usually depends upon weather conditions problems such as photovoltaic irradiance, the wind velocity, temp and also etc., the particular lack of stability from the system output result is usually paid for by having an appropriate energy storage space system towards the hybrid system. This can be to ensure the best stability really exist involving power demand and generated power.

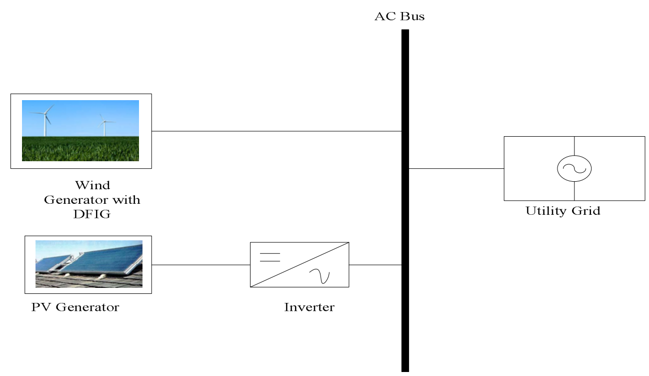

Figure 1. Proposed Hybrid Energy System structure

II. PHOTOVOLTAIC GENERATOR SIDE

Solar cell is simply a p-n junction over a slim wafer regarding semiconductor. Many like solar panels form the building block of a solar array [2]. The photovoltaic or PV power generator is composed of a variety of amount of solar panels attached including series and parallel. However, the performance regarding photovoltaic or PV depends upon irradiation and temperatures. The electromagnetic radiation regarding power from the sun is usually right transformed into electrical power through photovoltaic effect. Photovoltaic process are increasingly significant while environmentally friendly power source as it doesn't have a energy resource charge, since it isn't going to pollute, require less maintenance, no noise and many others.

The type of the photovoltaic cell could be realized by simply a good comparative circuit of which is made up of current source throughout parallel having diode. The current source signifies the current generated by the photons (denoted while I_{ph}) as well as output is constant within temperatures and constant radiation of light. R_s and R_{sh} parts can be neglected to the ideal type.[3]

The process of modeling this solar cell can be developed based on equations (1),(2) and (3).

$$I_d = I_s\left[\exp\left(\frac{V}{V_d}\right)-1\right] \quad (1)$$

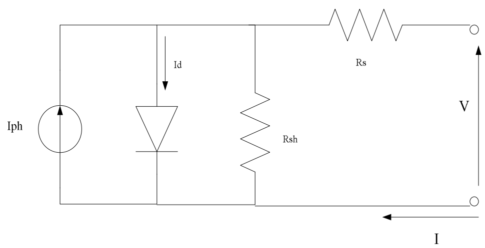

Figure 2. Basic model of PV cell

Being the net current of the cell, the difference of the photocurrent I_{ph} and the diode current I_d is shown in equation (2).

$$I = I_{ph} - I_d \quad (2)$$

Additionally equation (3) represents the simplified model [3].

$$I = I_{ph} - I_s\left[\exp\left(\frac{V}{V_d}\right)\right]-1 \quad (3)$$

III. WIND GENERATION SIDE

A. Wind Turbine Modelling

Wind electricity conversion methods utilized to get the vitality available in the wind to convert directly into electrical power. The windmill captures the wind's kinetic energy inside the rotor consisting of two or more blades mechanically coupled to an electrical generator. The principle element of the particular mechanical assembly is the gearbox, which makes over the slower rotational speed of the windmill to higher rotational speed on the electrical generator side. [4] The rotation of the electro-mechanical generator's shaft driven by wind turbine produces electrical power, whose output is maintained as per specifications; by utilizing acceptable manage along with supervisory tactics. Besides monitoring the output, these kinds of system includes protection methods to shield the overall program.

The power received because of the wind turbine can be a purpose of wind speed. This purpose often has any shape for example proven with Fig 3. [4] For variable speed WECS top of the part of the necessities in between and may always be kept linear, comparable to the reference power.

Power generated by a wind turbine is given by

$$P_m = 0.5\Pi\rho C_p(\lambda,\beta)R^2 v_w{}^3 \quad (4)$$

Where R is the turbine radius, v_m is the wind speed, ρ is the air density, C_p is the power coefficient, λ is the tip speed ratio and β is the pitch angle.

In this work β is set to zero. The tip speed ratio is given by

$$\lambda = \frac{\omega_r R}{v_w} \quad (5)$$

Where ω_r is the turbine angular speed.

The dynamic equation of the wind turbine is given as

$$d\omega_r / dt = (1/J)[T_m - T_l - F\omega_r] \quad (6)$$

Where J is the system inertia, F is the viscous friction coefficient, Tm is the torque developed by the turbine, T_l is the torque due to load which in this case is the generator torque. The target optimum power from a wind turbine can be written as

$$P_{\max} = K_{opt}\,\omega^3{}_{r\_opt} \quad (7)$$

Where

$$K_{opt} = \frac{0.5\Pi\rho C_{p\max} R^5}{\lambda_{opt}{}^3} \quad (8)$$

$$\omega_{opt} = \frac{\lambda_{opt} v_w}{R} \quad (9)$$

Fig 3 shows turbine mechanical power as a function of rotor speed at various wind speeds. The power to get a selected wind speed is actually utmost for a certain value connected with rotor speed referred to as optimum rotor speed ω_{opt}. Here is the velocity which often refers to optimum tip speed ratio λ_{opt}. As a way to possess utmost achievable power, wind turbine will most likely to run with λ_{opt}. It is achievable by means of handling the rotational speed with the wind turbine so that it always rotates on the optimum speed of rotation.[4][5].

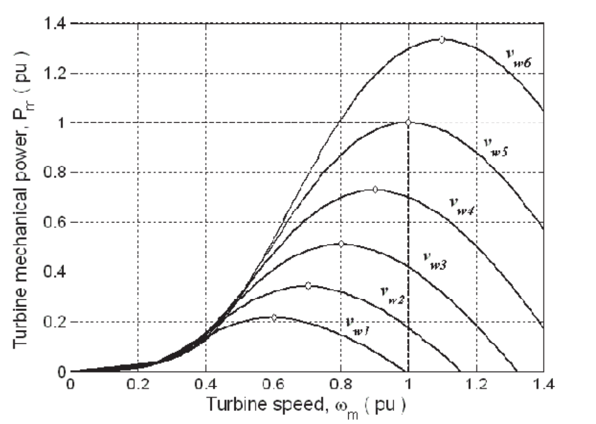

Figure 3. Mechanical power as a function of rotor speed for various wind speeds. [4]

B. DFIG Model

The DFIG model regulates the active as well as reactive power and makes sure the functioning of power factor. The output of the stator powers into grid at all times. The rotor, based on the functioning stage, is actually feeding power into grid when slip is negative (over synchronous operation) and it also absorbs power from the grid when slip is positive (sub-synchronous operation).[5] One advantage of this kind of setup is actually it's suitability with regard to grid-connected functions exactly where reactive power comes by the grid. When modeling the DFIG, the generator convention will be used, i.e. the currents are outputs instead of inputs and real power and reactive power have a positive sign when they are fed into the grid.[6] The equation are as follows:

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\phi_{ds} - \omega_e \phi_{qs} \qquad (10)$$

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\phi_{qs} + \omega_e \phi_{ds} \qquad (11)$$

$$V_{dr} = R_r i_{dr} + \frac{d}{dt}\phi_{dr} - (\omega_e - \omega)\phi_{qr} \qquad (12)$$

$$V_{qr} = R_r i_{dr} + \frac{d}{dt}\phi_{qr} + (\omega_e - \omega)\phi_{dr} \qquad (13)$$

The stator and rotor fluxes are given as :

$$\phi_{ds} = L_s i_{ds} + M i_{dr} \qquad (15)$$

$$\phi_{qs} = L_s i_{qs} + M i_{qr} \qquad (16)$$

$$\phi_{dr} = L_r i_{dr} + M i_{ds} \qquad (17)$$

$$\phi_{qr} = L_r i_{qr} + M i_{qs} \qquad (18)$$

Where R_s, R_r, L_s, L_r are the resistance and inductances of the stator and the rotor windings respectively, M is the mutual inductance.

V_{ds}, V_{qs}, V_{dr}, V_{qr}, are the d and q components of the stator and rotor voltages, i_{ds}, i_{qs}, i_{dr}, i_{qr}, $\square_{ds}$, $\square_{qs}$, $\square_{dr}$ and $\square_{qr}$ are the d and q components of the currents and flux, whereas ω is the rotor speed in electrical degree and ω_e is the angular velocity of the synchronously rotating frame [7].

The electromagnetic torque is expressed as:

$$C_e = P * \frac{M}{L_r}\left(\phi_{dr} * I_{qs} - \phi_{qr} * I_{ds}\right) \qquad (19)$$

Where P is the number of pole pairs. The active and reactive powers at the stator side and at the rotor side are as follows [8]:

$$P_s = (V_{ds} i_{ds} + V_{qs} i_{qs}) \qquad (20)$$

$$Q_s = (V_{qs} i_{ds} - V_{ds} i_{qs}) \qquad (21)$$

$$P_r = (V_{dr} i_{dr} + V_{qr} i_{qr}) \qquad (22)$$

$$Q_r = (V_{qr} i_{dr} - V_{dr} i_{qr}) \qquad (23)$$

IV. GRID CONNECTED HYBRID WIND PV SYSTEM

The grid connected Hybrid PV system uses a centralized AC bus architecture. The generators are installed in one place and are connected to the AC bus. This AC bus supplies the power to the grid. Multi-source Hybrid system with right control incorporates a greater possibility of offering much better good quality and more reliable power to utilizes than a system based on a single resource [9,10]. Grid connected hybrid power system are connected in parallel with the central utility power grid and can be used at any location (rural or urban).[11]There are many types of grid connected architectures. Each process has its advantages and disadvantages. This kind of paper presents the particular centralized ac-bus structures. In this, the wind energy system is directly connected to the ac bus whereas the PV system is connected to an inverter and then to an ac bus. This ac bus is directly connected to the grid. Any hybrid program could possibly be made to work often within separated manner or perhaps within grid connected manner, as a result of electrical power electronic interface. The power electronic interface needs to be capable of take care of the hybrid age group program guidelines just like voltage, rate of recurrence for example, on approved (acceptable) amounts. [12] It is crucial to get a good control of the electrical power angle as well as the voltage amount by means of a great inverter and that is the leading stop of the electrical power electronic interface. Control of the inverter's result voltage as well as the electrical power angle controls the actual stream connected with real electrical power and reactive electrical power.[13]

V. SIMULATION AND RESULT

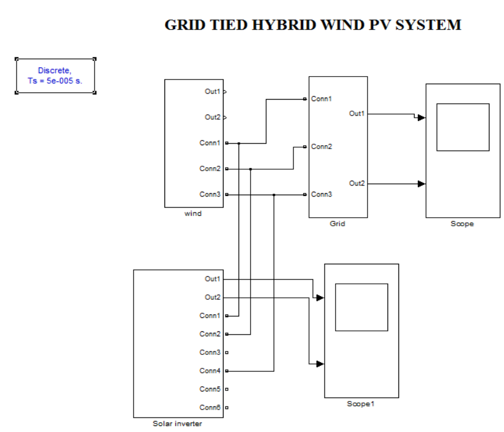

Figure 4. Simulink Model of Grid Tied Hybrid System

Fig 4 shows that the wind farm is directly connected to an ac bus. The PV system output is firstly converted into ac through an inverter which supplies power to an ac bus. This ac bus then connects to the utility grid.

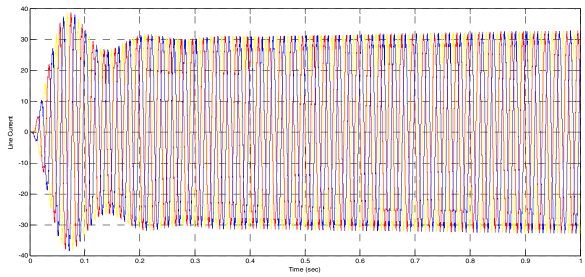

Figure 5. Line Current of Solar Inverter

Fig 5 shows the output of the solar inverter. This is the inverted voltage waveform.

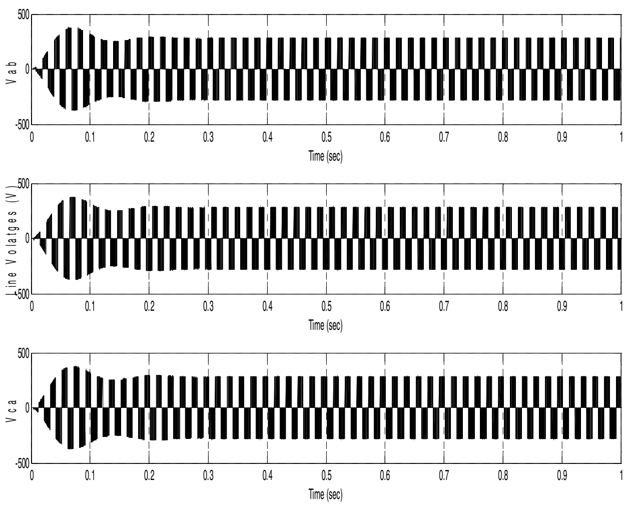

Figure 6. Line Voltages of Solar Inverter

Fig 5 and Fig 6 shows the line current and line voltages of solar inverter respectively. The line current of solar inverter initially rises to about 40 A and then stables at 0.4 sec to 30A. The line voltages rise to about 400 V and then stables at 0.2 sec to 250 V.

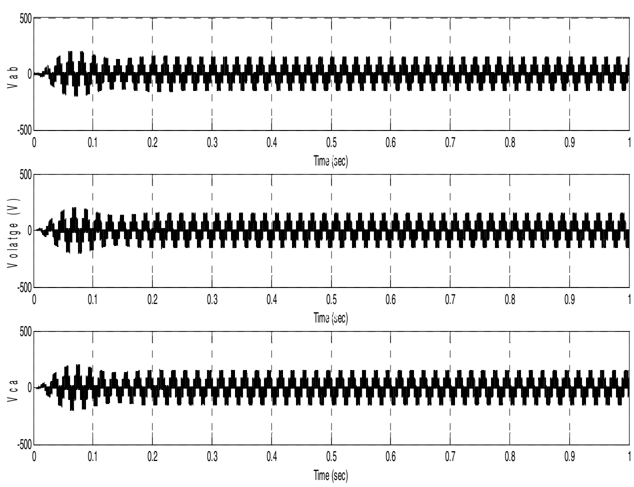

Figure 7: Output Voltage of Solar Inverter

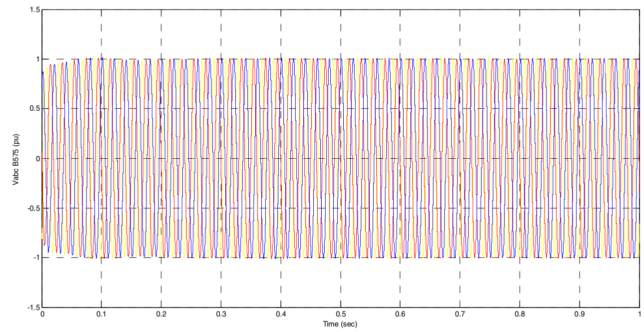

Figure 8. Output Voltage at Grid

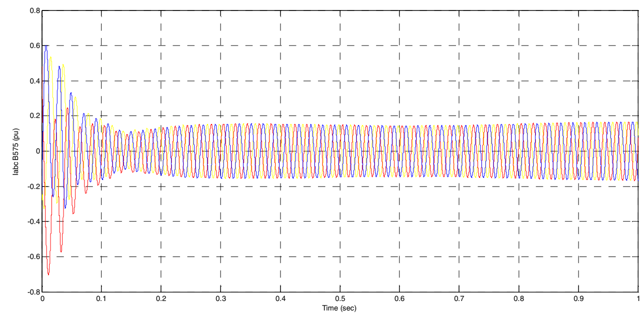

Figure 9. Output Current at Grid

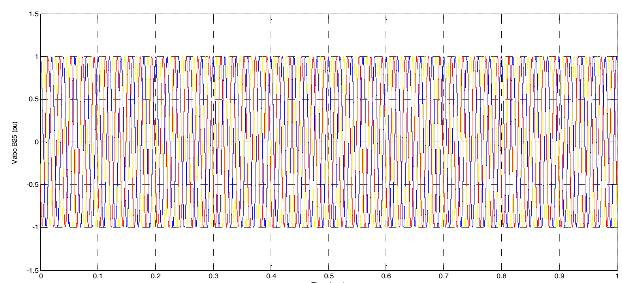

Figure 10. Output Voltage at Grid

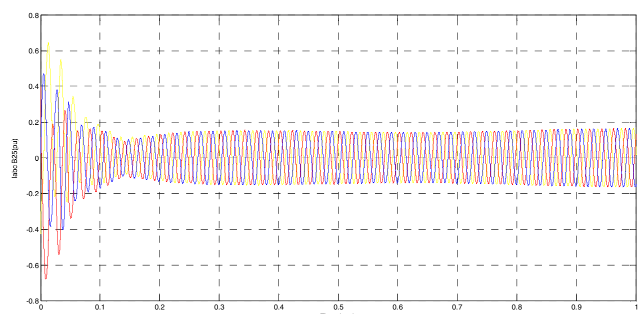

Figure 11. Output Current at Grid

The output voltage and current at the utility grid is shown in Fig 8 and Fig 9 respectively. The hybrid system is connected to a 25kV distribution system which gives the power to the 120kV grid through a 30km, 25kV feeder. Initially output current shows some distortion till 0.2 sec. After 0.2 sec the current goes in its stable position.

VI. CONCLUSION

From this analysis it is observed that it is possible to accurately predict the power output from grid connected photovoltaic arrays by including the effect of temperature and solar radiation. It is also possible to adapt the size of models and the different PV hybrid system configurations which are applicable to a grid connected. Upon achieving this, a side-by-side assessment associated with grid connected PV sizes and wind farm was performed. The design in this type was justified by looking at different measured values over the collection period; for example; energy output vs. rays, voltage vs. rays and output energy vs. temperatures. These kinds of plots presented gives a proper approval to the sizes and proportion associated with all those variables joining with grid. By using this software Simulink program, the maximum power output from hybrid system sizes and configurations can now be predicted with accuracy. The hybrid power system connected with an ac bus shows improved results with proper control.

REFERENCES

[1] Y. Jaganmohan Reddy, Y.V. Pavan Kumar, K.Padma Raju and Anilkumar Ramesh , "Retrofitted Hybrid Power System Design with Renewable Energy Sources for Buildings", IEEE Transactions on Smart Grid, Vol. 3, No. 4, December 2012, pp. 2174-2187.

[2] Jitendra Kasera, Ankit Chaplot, Jai Kumar Maherchandani , " Modeling and Simulation of Wind-PV Hybrid Power System using MATLAB/Simulaink" , 2012 IEEE students Conference on Electrical, Electronics and Computer Science, pp. 1-4.

[3] Jose Eduardo M. S. Paiva, Adriano S. Carvalho , " An Integrated Hybrid Power System Based on Renewable Energy Sources" , IEEE 2009,pp. 4548-4554.

[4] Abderrezzak Bouharchouche, El Madjid Berkouk, Tarrak Ghennam, " Control and Energy Management of a Grid Connected Hybrid Energy system PV- Wind with Battery Energy Storage for Residential Applications, 2013 Eighth International Conference and Exhibition on Ecological vehicles and Renewable Energies, March 2013, pp. 1-11.

[5] Nishad Mendis, Kashem M. Muttaqi, Saad Sayeef and Sarath Perera, " Standalone Operation of Wind Turbine- Based variable Speed Generators with Maximum Power Extraction Capability", IEEE Tractions on Energy Conversions, Vol. 27, No.4, December 2012,pp. 822-834.

[6] Seok-II Go, Seon-Ju Ahn, Joon-Ho Choi, Won-Wook Jung, Sang-Yun Yun and II-Keun Song, " Simulation and Analysis of Existing MPPT Control Methods in a PV Generation System", Journal of International Council on Electrical Engineering Vol.1, No.4, pp. 446-451, 2011

[7] Bindu U. Kansara, B.R. Parekh, " Dispatch and Control Strategies for Isolated and Grid Connected Wind- Diesel Hybrid Electric Generating System", International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development ,Vol. 3, Issue 2, June 2013, pp. 152-156.

[8] Mehdi Dali, Jamel Belhadj, Xavier Roboam, "Theoretical and Experimental Study of Control and Energy Management of a Hybrid Wind- Photovoltaic System", IEEE 8th International Multi-Conference on Systems, Signals and Devices March 2011,pp. 1-7.

[9] Joanne Hui, Alireza Bakhshai and Praveen K. Jain, " A Hybrid Wind-Solar Energy System : A New Rectifier Stage Topology", IEEE Transactions on Energy Conversion, 2010, pp. 155-161.

[10] Mustafa Engin "Sizing and Simulation of PV-Wind Hybrid Power System", Hindawi Publising Corporation, International journal of Photoenergy Volume 2013, pp. 1-10

[11] Bogdan S. Borowy, Ziyad M. Salameh, "Dynamic Response of a stand-Alone Wind Energy Conversion System with Battery Energy Storage to a Wind Gust, IEEE Transactions on Energy Conversion, Vol.12, No.1, March 1997, pp. 73-78.

[12] Yousif El-Tous, "A Study of a Grid-connected PV Household System in Amman and the Effect of the Incentive Tariff on the Economic Feasibility", International Journal of Applied Science and Technology, Vol.2 No.2, February 2012, pp. 100-105.

[13] R. Valarmathi, S. Palaniswami, N. Devarajan, " Simulation and Analysis of Wind Energy and Photo Voltaic Hybrid System", International Journal of Soft Computing and Engineering, Vol. 2, Issue 2, May 2012, pp. 193-200.

[14] Sowmini Priya.S, Rajakumar.S, " An Energy Storage System for Wind Turbine Generators- Battery and Supercapacitor", International Journal of Engineering Research and Applications, Vol. 3, Issue 2 March-April 2013, pp. 1219-1223.

[15] Anumeha Awasthi, Kuldeep Sahay and Anuj yadav, "Simulation and Harmonics Reduction of Wind-PV Hybrid System", International Journal of Advanced Research in Computer Science and Software Engineering Vol.3, Issue 6, June 2013, pp. 980-982.

[16] N. Sambasiva Rao, "Design & Simulation of Hybrid Solar – Wind Electric Power System interface to Grid System", International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 4, Aug-Sep 2013, pp. 1-10

[17] J. Godson, M.Karthick, T. Muthukrishnan, M.S. Sivagamasundari, "Solar PV-Wind Hybrid Power Generation System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 11, November 2013, pp. 5350-5354.

[18] Lingfeng Wang and Chanan Singh, "Multicriteria Design of Hybrid Power Generation Systems Based on a Modified Particle Swarm Optimization Algorithm", IEEE Transactions On Energy Conversion, Vol. 24, No. 1, March 2009, pp. 163-172.

[19] Xiong Liu, Peng Wang, Poh Chiang Loh, "A Hybrid AC/DC Micro-Grid", IEEE Power Engineering Division, School of Electrical and Electronic Engineering Nanyang Technological University, Singapore, 2010, pp. 746-751.

[20] Subhadarshi Sarkar and Venkataramana Ajjarapu, "MW Resource Assessment Model for a Hybrid Energy Conversion System With Wind and Solar Resources", IEEE Transactions On Sustainable Energy, Vol. 2, No. 4, October 2011, pp. 383-391.

[21] Jianwu Zeng, Wei Qiao*, and Liyan Qu, "An Isolated Multiport DC-DC Converter for Simultaneous Power Management of Multiple Renewable Energy Sources", 2012 IEEE, pp. 3741-3748.

[22] Sindhu.D, Aswinudhaya.R, "Analysis of the Performance of Hybrid AC/DC Microgrid by Using D-Q Transformation", 2013 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2013], pp. 107-114.

[23] J. Bhagwan Reddy, "Probabilistic Performance Assessment of a Roof Top Wind, Solar Photo Voltaic Hybrid Energy System", 2004 Jan, IEEE, pp. 654-658.