ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Study on Wind-solar Hybrid Generating System Control Strategy: Comparison of P&O and IC MPPT Techniques

Vani Angeri
M.Tech Student (EPS),
JB Institute of Engineering and Technology
(UGC Autonomous), Hyderabad.

K.Giribabu
Assistant Professor,
Dept of EEE,
J.B Institute of Engineering and Technology
(UGC Autonomous), Hyderabad.

Abstract:

With the complementary characteristics between wind and photovoltaic, wind-solar hybrid generating system take advantage of the intervals wind and photovoltaic to make the stable technology output by the control strategy of transformation, charging and storage and so on. This paper also explores two maximum power point tracking (MPPT) techniques, i.e. the Incremental Conductance (IC) and Perturb and Observe (P&O) techniques. For making maximum use of the wind and solar energy, this paper apply the Maximum Power Point Tracking control method to the global power of the wind-solar hybrid generating system according to the basic principle of the variable step perturbation tracking maximum power point algorithm. Due to the common DC/DC charging controlling unit adopted in the paper, both the whole circuit and control process are simplified to some extent. According to analyzing the mathematical models and the control strategies of the pv array and wind power generation, the paper use the Simulink of the matlab software to simulate the whole Wind-solar Hybrid Generating System.

Key words:

Wind-solar hybrid generating system; MPPT control; matlab/simulink.

1. Introduction:

Electricity is one of the greatest launchings of the mankind. With its discovery, it has been the driving force for economic development of the world and integral part for enhancing the quality of lives. Wind power generation systems and solar power generation system is, respectively, converting wind and solar power into electric energy, and charging the battery through the controller, then supplying the power to the load by the inverter. Supported by the wind or solar power separately, it is easy to cause the supply and load not to match that l affect the output power quality of the system. In view of the strong complementarity of solar and wind power in the time way, Wind-solar Hybrid Generating System is considered to take full advantage of renewable energy so greatly as to improve the stability and reliability of the power system, and save the cost of the electricity to a certain extent by reducing the capacity of the battery and extending the life of the battery. A small "hybrid" electric system that combines wind and solar (photovoltaic) technologies offers several advantages over either single system. The most important asset of hybrid system is that it has the potential to provide the quality electricity all year around where battery is used in standalone system.In order to improve the generating efficiency of the Wind-solar Hybrid Generating System, it is necessary to make the full of the wind power and photovoltaic power generation as much as possible. Accordingly both the wind and solar power can adopt the Maximum Power Point Tracking (MPPT) method to improve the generating efficiency.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The MPPT control have many control methods, such as fixed voltage tracking method, power feedback method, disturbance observer method and so on. The paper[1] control the Wind-solar Hybrid Generating System separately according to the output characteristic curve of the wind and solar power. Whereas the control method increase the complexity of the proposed techniques and production cost. So this paper proposed a method by means of controlling the total output power of wind power and photovoltaic power generation by MPPT to tracking the maximum power. By comparing and analyzing a variety of MPPT control algorithm, this paper adopts the variable step maximum power point tracking algorithm, which tracks the maximum charging power of the battery pack for realizing the MPPT control of wind and solar system[2][3]. So when it is lack of sunlight in the morning and evening the MPPT control tracks the maximum power of wind power mainly, otherwise the maximum power of photovoltaic power generation at noon. By the simulation with MATLAB/SIMULINK software, it is verified that the control method adopted in this paper not only ensure tracking the maximum power of the wind and solar power generation system on the operating process.When a solar cell is operating without a MPPT technique, the power drawn from the PV cell is determined by the load. When MPPT is implemented, the MPPT technique will regulate the amount of power drawn from the PV cell by regulating the duty cycle of the DC-DC converter. The MPPT technique will also ensure that the PV cell does not operate close to open circuit voltage or short circuit current. The implementation of standalone PV-Wind Hybrid system is shown in Fig. 1. This paper will investigates the two MPPT techniques, out of which Incremental Conductance (IC) and Perturb and Observe (P&O) Modelling of a PV-Wind Hybrid system and DC-DC converter is detailed and finally experimental validation of the simulated PV-Wind Hybrid model and the IC technique is performed. In a hybrid system with a centralized inverter setup, as shown in Fig. 1, the output of dc–dc converters is sent to an external dc–ac inverter to supply ac power to load.

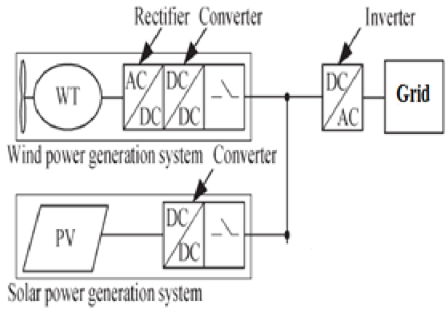

Figure 1: Block diagram of hybrid solar and wind power generation system

2. PV and Wind and Energy System

Wind and solar hybrid is composed of some controllers such as wind power generation, solar power generation, battery and inverter. The double-fed asynchronous is widely used as the generator in wind power generation, and power electronics interface achieves power regulation and transformation with both bridge-rectifier and DC/DC converter. Because the randomness of wind is strong, a controller is needed to adjust the speed to ensure the maximum utilization factor of wind power when the wind speed is less than the rated, and ensure the output power of the fan to maintain the rating when the wind speed exceeds rated. When the output power of the fan is too large, if you still need to charge the battery, then part of the power must be removed through uninstalling the circuit in order to avoid damage of generation system [4].The photovoltaic generation part adopts photovoltaic cell array, and achieves output power regulation and transformation with DC/DC converter. Battery is the reservoir core of the whole photovoltaic generation system, thus its charge control is rather critical. By detecting voltage and current respectively to realize the maximum power and three-stage charge control of battery. At the beginning of charging, in order to get quick control over the charge of battery, it is charged with the maximum allowable current. If the polarization responses occur at the time the terminal voltage reaches the set value, the charging current should be ensured in allowable value. Electric energy generated by wind power and solar power must be

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

converted to the adequate AC and DC by power electronic converter to supply the load. This converter could adopt the circuit composed of the power converters, energy storage of mutual inductance and voltage load.

3. PV Array Characteristics

The use of single diode equivalent electric circuit makes it possible to model the characteristics of a PV cell. The mathematical model of a photovoltaic cell can be developed using MATLAB simulink toolbox. The basic equation from the theory of semiconductors that mathematically describes the I-V characteristic of the Ideal photovoltaic cell is given by

$$I = I_{pvcell} - I_d \qquad (1)$$

Where,

$$I_d = I_{0cell}[\exp(qv/\alpha kT)-1] \qquad (2)$$

Therefore

$$I = I_{pvcell} - I_{0cell}[\exp(qv/\alpha kT)-1] \qquad (3)$$

Where, 'I_{PVCell}' is the current generated by the incident light (it is directly proportional to the Sun irradiation), I_d is the diode equation, Io, cell' is the reverse saturation or leakage current of the diode, 'q' is the electron charge [1.60217646* 10−19C], k is the Boltzmann constant [1.3806503 *10−23J/K], 'T' is the temperature of the *p-n* junction, and 'a' is the diode ideality constant. Fig.2 shows the equivalent circuit of ideal PV cell.

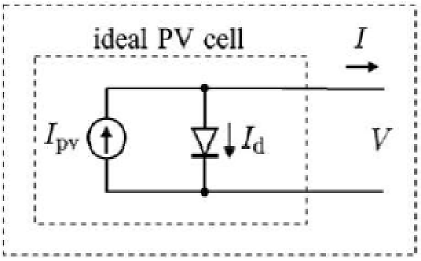

Fig.2 Equivalent circuit of ideal PV cell

Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV array requires the inclusion of additional parameters (as shown in Fig.8) to the basic equation:

$$I = I_{pv}-I_o[\exp(V+IR_s/V_t\alpha)-1]-(V+IR_s/R_p) \quad (4)$$

Where Vt = NskT/q is the thermal voltage of the array with 'Ns' cells are connected in series. Cells connected in parallel increases the current and cells connected in series provide greater output voltages. *V* and *I* are the terminal voltage and current. The equivalent circuit of ideal PV cell with the series resistance (Rs) and parallel resistance (Rp) is shown in Fig.3.

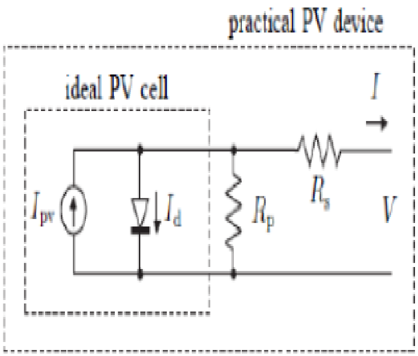

Fig.3 Equivalent circuit of ideal PV cell with Rp and Rs.

For a good solar cell, the series resistance (Rs), should be very small and the shunt (parallel) resistance (Rp), should be very large. For commercial solar cells (Rp) is much greater than the forward resistance of a diode. The I-V curve is shown in Fig.4. The curve has three important parameters namely open circuit voltage (Voc), short circuit current (Isc) and maximum power point (MPP). In this model single diode equivalent circuit is considered. The I-V characteristic of the photovoltaic device depends on the internal characteristics of the device and on external influences such as irradiation level and the temperature.

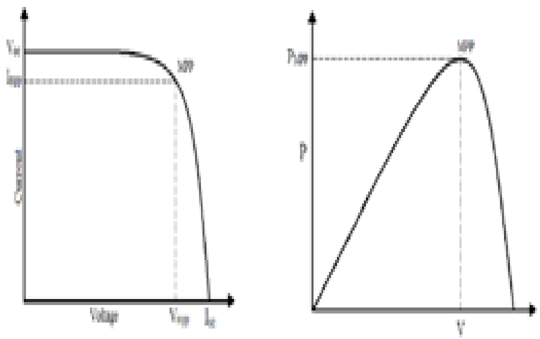

Fig.4 I-V and P-V characteristics of PV cell

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

4. Wind Energy Conversion System

In order to capture the maximal wind energy, it is necessary to install the power electronic devices between the wind turbine generator (WTG) and the grid where the electrical power delivered by the generator to the load can be dynamically controlled and the frequency is constant. The instantaneous difference between mechanical power and electrical power changes the rotor speed following the equation

$$J\frac{d\omega}{dt} = \frac{P_m - P_e}{\omega} \quad (4)$$

Where *J* is the polar moment of the inertia of the rotor

(neglecting friction coefficient *B*), ω is the angular speed of the rotor, *Pm* is the mechanical power produced by the turbine, and *Pe* is the electrical power delivered to the load. The input of a wind turbine is the wind and the output is the mechanical power turning the generator rotor [4]. For a variable speed wind turbine, the output mechanical power available from a wind turbine could be expressed as

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

where ρ and *A* are the air density and the area swept by blades, respectively. *Vw* is the wind velocity (m/s), and *CP* is called the power coefficient, and is given as a nonlinear function of the tip speed ratio λ defined by

$$\lambda = \frac{\omega_r R}{V_\omega} \quad (6)$$

where R is the turbine blade radius, and *r* □ is the turbine speed. *CP* is a function of λ and the blade pitch angle β. The variable-speed pitch-regulated wind turbine is considered in this paper, where the pitch angle controller plays an important role. Fig. 5 shows the groups of *CP* - λ at different pitch angles and speed- power curves of the wind turbine used in this study at different wind velocities. It is noted from the figure that *CP* can be changed either by adjusting the pitch angle β or Tip speed ratio λ. Here considering constant pitch, In other words, the output power of the wind turbine can be regulated by the TSR control.

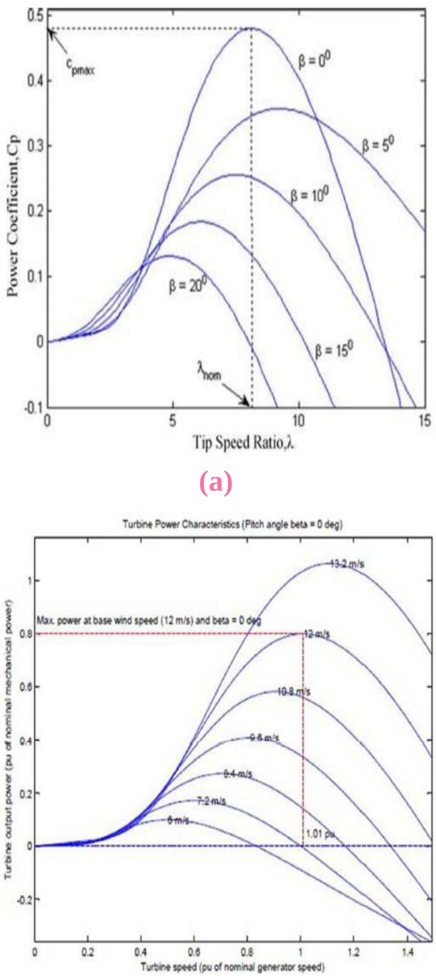

Fig. 5 (a) Characteristics of the WECS at different pitch angles. (b) Turbine power characteristics (pitch angle beta =0 deg).

5. MPPT ALGORITHMS

5.1 Perturb and Observe (P&O) Algorithm

A slight perturbation is introduced in this algorithm. The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same direction. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the steady state is reached. The perturbation size is kept very small in order to keep the power variation small [1].

The algorithm can be easily understood by the following flow chart which is shown in Fig.6.

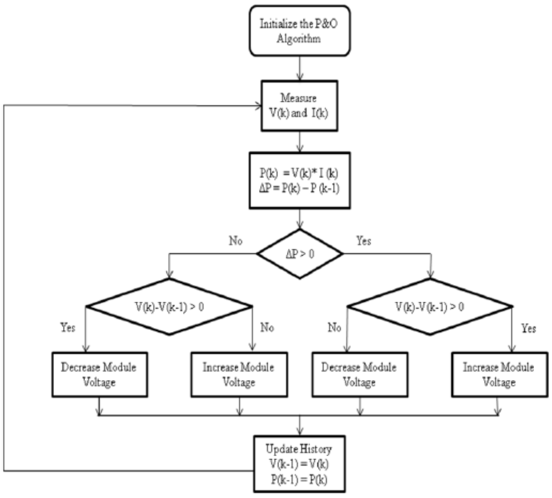

Fig.6 Perturb and Observe Algorithm

In this technique, first the PV voltage and current are measured and hence the corresponding power P1 is calculated. Considering a small perturbation of voltage (ΔV) or perturbation of duty cycle (Δd) of the dc/dc converter in one direction corresponding power P2 is calculated. P2 is then compared with P1. If P2 is more than P1, then the perturbation is in the correct direction; otherwise it should be reversed. In this way, the peak power point (Pmpp) is recognized and hence the corresponding voltage (Vmpp) can be calculated. The major drawbacks of P&O are occasional deviation from the maximum operating point in case of rapidly changing atmospheric conditions, such as broken clouds. Also, correct perturbation size is important in providing good performance in both dynamic and steady-state response.

5.2 Incremental Conductance (IC) Algorithm

Incremental Conductance (IC) method overcomes the disadvantage of the perturb and observe method in tracking the peak power under fast varying atmospheric condition [2]. The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart which is shown in Fig.7.

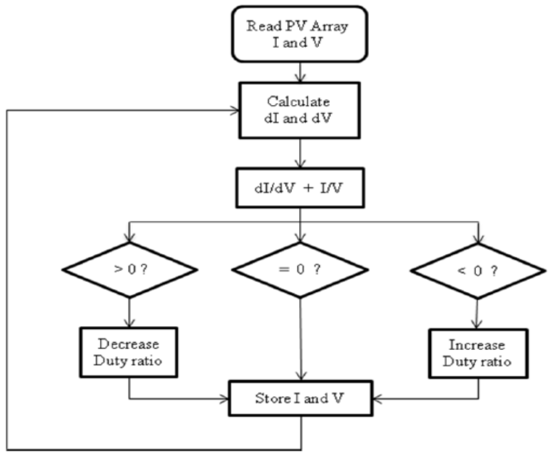

Fig.7 Incremental Conductance Algorithms

For a PV system, the derivative of panel output power with its voltage is expressed as

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} = I + V\frac{\Delta I}{\Delta V} \qquad (7)$$

Thus, MPP can be tracked by comparing the instantaneous conductance I/V to the incremental conductance ΔI/ΔV. It is the same efficient as P&O, good yield under rapidly changing atmospheric conditions. Here, also the same perturbation size problem as the P&O exists and an attempt has been made to solve by taking variable step size. But, it requires complex and costly control circuits.

6. SIMULATION RESULTS

The simulation circuit of proposed RSC circuit is shown in Fig.12. The simulation circuit of perturb and observe MPPT method is shown in Fig.13. The simulation circuit of Incremental Conductance MPPT method is shown in Fig.14.

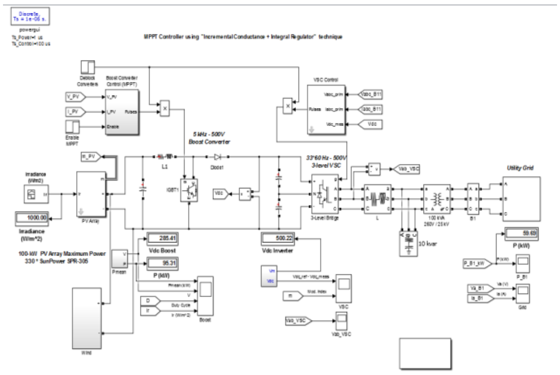

Fig.8 Simulation Circuit of Hybrid PV-Wind System

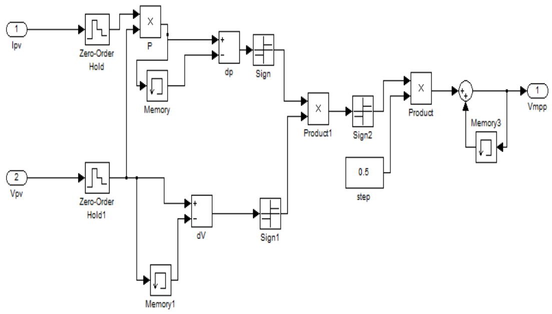

Fig. 9 P&O MPPT

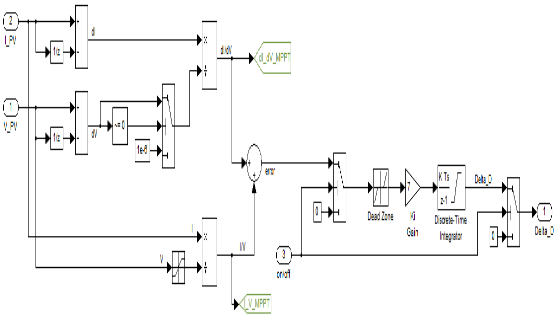

Fig. 10 Incremental Conductance MPPT

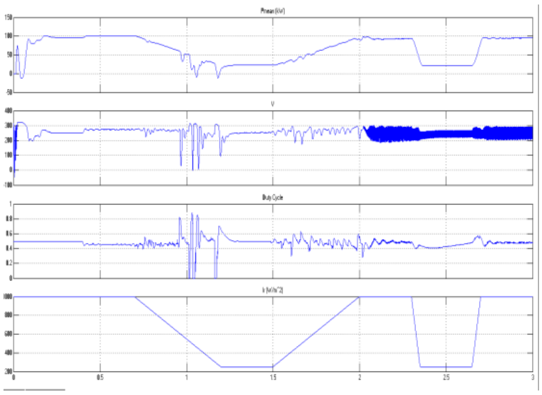

Fig. 11 PV output Voltage

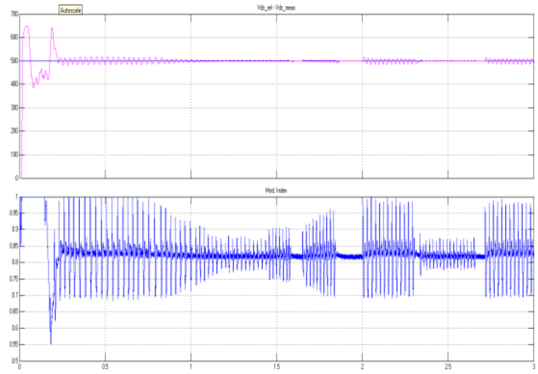

Fig. 12 DC link Voltage with P&O MPPT

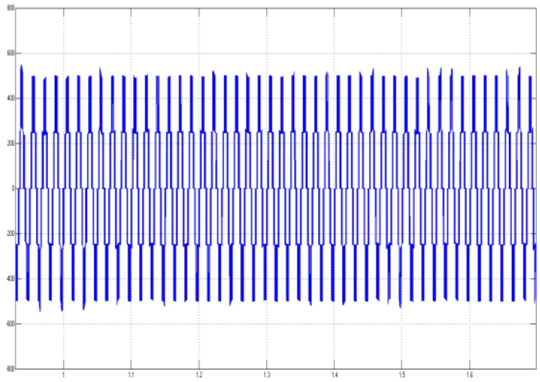

Fig. 13 Inverter Output Voltage with P&O MPPT

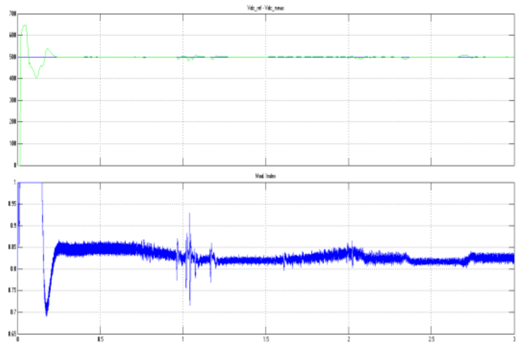

Fig.14 DC Link Voltage with INC

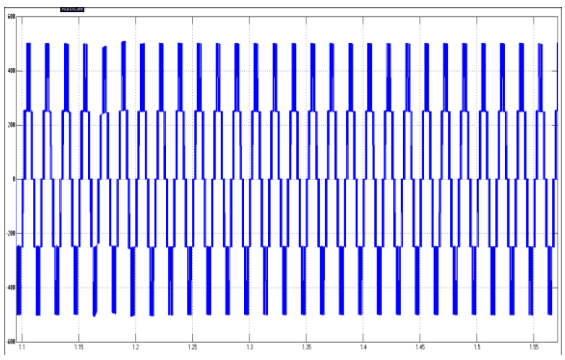

Fig.15 Inverter Output Voltage with INC

Fig.11 shows the output voltage of PV. The DC link voltage with P&O MPPT method is shown in Fig.12. The DC link voltage with Incremental Conductance MPPT method is shown in Fig.14. By comparing Fig.12&Fig.14, the DC link voltage is high with INC MPPT method. Fig.13 shows the inverter output voltage with P&O MPPT method. Fig.15 shows the inverter output voltage with INC MPPT method. By comparing Fig.13&Fig.15, the inverter output voltage is high with INC MPPT method.

7. CONCLUSION

Wind/PV hybrid power system has a good application prospect. In order to achieve optimal and reliable operation of the system, both energy flow and operation characteristics are analyzed in this paper. Operation modes and working states of stand-alone wind/PV power systems are also summarized. Integration of Solar snd Wind with proper control strategy for better coordination is presented in this paper. This paper also provides a classification of available MPPT techniques based on the number of control variables involved, types of control strategies, circuitry, and cost of applications, which is possibly useful for selecting an MPPT technique for a particular application.

REFERENCES

[1] S.-K. Kim, J.-H. Jeon, C.-H. Cho, J.-B. Ahn, and S.-H. Kwon, “Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer,” IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1677–1688, Apr. 2008.

[2] K. Kobayashi, H. Matsuo, and Y. Sekine, “An excellent operating point tracker of the solar-cell power supply system,” IEEE Trans. Ind. Electron., vol. 53, no. 2, pp. 495–499, Apr. 2006.

[3] K. Kobayashi, H. Matsuo, and Y. Sekine, “Novel solar-cell power supply system using a multiple-input dc–dc converter,” IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 281–286, Feb. 2006.

[4] A. I. Bratcu, I. Munteau, S. Bacha, D. Picault, and B. Raison, “Cascaded dc–dc converter photovoltaic systems: Power optimization issues,” IEEE Trans. Ind. Electron., vol. 58, no. 2, pp. 403–411, Feb. 2011.

[5] W. Li, G. Joos, and J. Belanger, “Real-time simulation of a wind turbine generator coupled with a battery supercapacitor energy storage system,” IEEE Trans. Ind. Electron., vol. 57, no. 4, pp. 1137–1145, Apr. 2010.

[6] F. Valenciaga and P. F. Puleston, “Supervisor control for a stand-alone hybrid generation system using wind and photovoltaic energy,” IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 398–405, Jun. 2005.

[7] S. Meenakshi, K. Rajambal, C. Chellamuthu, and S. Elangovan, “Intelligent controller for a stand-alone hybrid generation system,” in Proc. IEEE Power India Conf., New Delhi, India, 2006.

[8] P. E. Kakosimos and A. G. Kladas, "Implementation of photovoltaic array MPPT through fixed step predictive control technique," Renewable Energy, vol. 36, pp. 2508-2514, Sep 2011.

[9] D. Peftitsis, et al., An investigation of new control method for MPPT in PV array using DC/DC buck - boost converter, 2008.

[10] F. Liu, et al., "A variable step size INC MPPT method for PV systems," Ieee Transactions on Industrial Electronics, vol. 55, pp. 2622-2628, Jul 2008.

[11] A.S. Samosir and A. H. M. Yatim, "Dynamic evolution control for synchronous buck dc-dc converter, Theory, model and simulation, Elsevier, vol. 18, pp. 663-676, 2010.

[12] C.-H. Lin, et al., "Maximum photovoltaic power tracking for the PV array using the fractional-order incremental conductance method," Applied Energy, vol. 88, pp. 4840-4847, Dec 2011.

[13] R. V. Dell Aquila, "A new approach: Modelling, simulation, development and implementation of a

commercial grid-connected transformerless PV inverter," 2010, pp. 1422-1429.

[14] R. M. da Silva and J. L. M. Fernandes, "Hybrid photovoltaic/thermal (PV/T) solar systems simulation with Simulink/Matlab," Solar Energy, vol. 84, pp. 1985-1996, 2010.

[15] L. Zhang, et al., "A New Approach to Achieve Maximum Power Point Tracking for PV System With a Variable Inductor," IEEE Transactions on Power Electronics, vol. 26, pp. 1031-1037, Apr 2011.

[16] A. M. O. Haruni, A. Gargoom, M. E. Haque, and M. Negnevitsky, "Dynamic operation and control of a hybrid wind-diesel stand alone power systems," in Proc. IEEE APEC, Feb. 2010, pp. 162–169.

[17] D. B. Nelson, M. H. Nehrir, and C. Wang, "Unit sizing of stand-alone hybrid wind/pv/fuel cell power generation systems," in Proc. IEEE Power Eng. General Soc. Meeting, Jun. 2005, vol. 3, pp. 2116–2122.

[18] M. C. Chandorkar, D. M. Divan, and R. Adapa, "Control of parallel connected inverters in standalone ac supply systems," IEEE Trans. Ind. Appl., vol. 29, no. 1, pp. 136–143, Jan./Feb. 1993.

[19] J. M. Guerrero, J. Matas, L. G. de Vicuna, M. Castilla, and J. Miret, "Wireless-control strategy for parallel operation of distributed-generation inverters," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1461–1470, Oct. 2006.

Author's Details:

Angeri Vani received B. Tech Degree in Electrical and Electronics Engineering from Vidhya Jyothi Institute of Technology (JNTUH) in the year of 2013. She is currently M. Tech student in the Energy Systems, JB Institute of Engineering and Technology (UGC Autonomous), Hyderabad, India. And she is interested in the field of Power System and Renewable Energy Systems.

K.Giribabu received the B.Tech degree in Electrical & Electronics Engineering from RVR & JC College of Engineering affiliated to Acharya Nagarjuna University, Guntur in 2005, the M.TECH degree in Electrical Power systems from RVR & JC College of Engineering affiliated to Acharya Nagarjuna University, Guntur in 2007, he was currently working as Assistant Professor at J. B. Institute of Engineering and Technology, Affiliated to JNTU Hyderabad, India. His area of interest include power system.