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A Comparitive Study of Solar MPPT Control Techniques

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Abstract: In the future, solar energy will be a very important energy source. Several studies suppose that more than 45% of the energy in the world will be generated by photovoltaic array. Therefore it is necessary to concentrate our forces to re-duce the application costs and to increment their performance. In order to reach the last aspect, it is important to note that the output characteristic of a photovoltaic array is nonlinear and changes with solar irradiation and cell's temperature. Therefore a Maximum Power Point Tracking (MPPT) technique is needed to maximize the produced energy. This paper presents a comparative study of seven widely-adopted MPPT algorithms; their performance is evaluated using, for all the techniques, a common device with minimum hardware variations. In particular, this study compares the behaviors of each technique in presence of solar irradiation variations.

Key words: MPPT · P&O · Photovoltaic · Maximum Power

INTRODUCTION

Solar energy is one of the most important renewable energy sources. As opposed to the conventional not renew-able sources such as gasoline, coal, etc. solar energy is clean, inexhaustible and free. The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic and street lighting, electric vehicles, military and space applications) or grid-connected configurations (hybrid systems, power plants). Unfortunately, PV generation systems have two major problems: the conversion efficiency in electric power generation is low (in general less than 17%, especially under low irradiation conditions) and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell V-I characteristic is nonlinear and changes with irradiation and temperature. In general, there is a point on the V-I or V-P curve only, called the Maximum Power Point (MPP), at which the entire PV system (array, inverter, etc.) operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Maximum Power Point Tracking (MPPT) techniques are used to maintain the PV array's operating point at its MPP [1-5].

Many MPPT techniques have been proposed in the literature; examples are the Perturb and Observe (P&O) method the Incremental Conductance (IC) method the Artificial Neural Network method the Fuzzy Logic method etc.. The P&O and IC techniques, as well as variants thereof, are the most widely used. Because of the large number of methods for MPPT, in the last years researchers and practitioners in PV systems have presented survey or comparative analysis of MPPT techniques. As a matter of fact, some papers present comparative study among only few methods and one paper presents a survey and a discussion of several MPPT methods. Another paper presents a ranking of ten widely adopted MPPT algorithms (P&O, modified P&O, Three Point Weight Comparison Constant Voltage, IC, IC and CV combined Short Current Pulse, Open Circuit Voltage the Temperature Method and methods derived from it), based on simulations, under the energy production point of view. The MPPT techniques are evaluated considering different types of insolation and solar irradiance variations and calculating the energy supplied by a complete PV array [6].

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Different MPPT Techniques: There are different techniques used to track the maximum power point. Few of the most popular techniques are:

- Perturb and observe (hill climbing method)
- Incremental Conductance method
- Fractional short circuit current
- Fractional open circuit voltage
- Neural networks
- Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

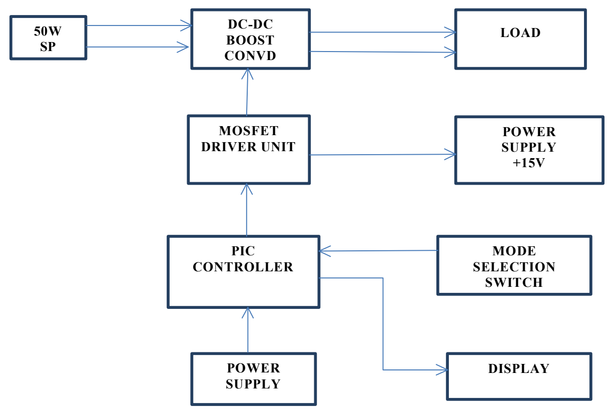
Perturb & Observe: Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method [6, 7].

Incremental Conductance: Incremental conductance method uses two voltage and current sensors to sense the output

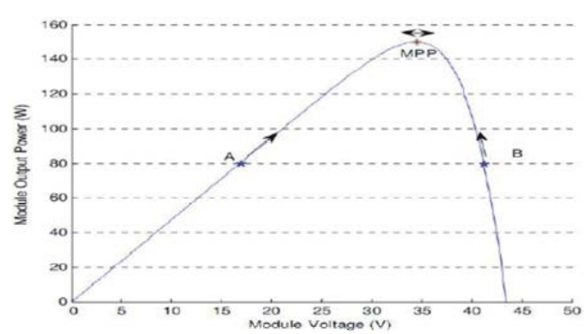
Voltage and current of the PV array.
At MPP the slope of the PV curve is 0.
(dP/dV)MPP=d(VI)/dV (4.1)
0=I+VdI/dVMPP (4.2)
dI/dVMPP = - I/V (4.3)

The fig shows the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached. Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However the complexity and the cost of implementation increases. As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms. Owing to its simplicity of implementation we have chosen the Perturb & Observe algorithm for our study among the two.

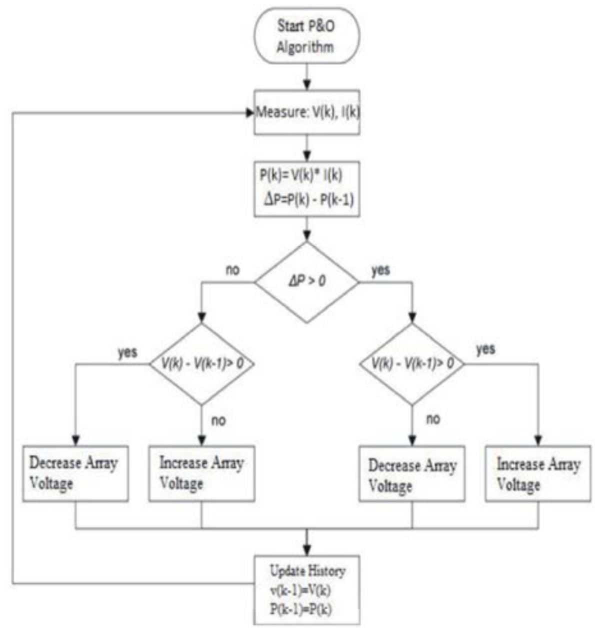
Block Diagram of MPPT



Perturb and Observe Algorithm: The Perturb & Observe algorithm states that when the operating voltage of the PV panel is perturbed by a small increment, if the resulting change in power #P is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If #P is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed. Shows the plot of module output power versus module voltage for a solar panel at a given irradiation. The point marked as MPP is the Maximum Power Point, the theoretical maximum output obtainable from the PV panel. Consider A and B as two operating points [8-10].

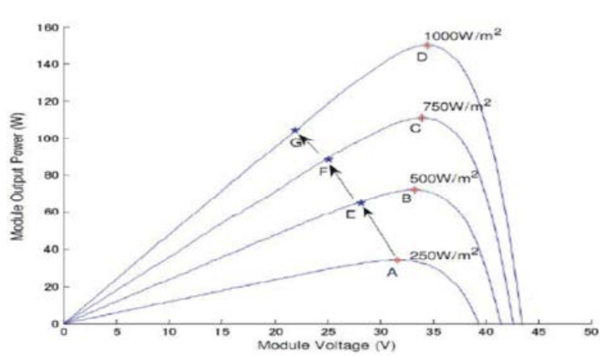


Module voltage vs module output power



Flowchart of Perturb & Observe algorithm

Limitations of Perturb & Observe Algorithm: In a situation where the irradiance changes rapidly, the MPP also moves on the right hand side of the curve. The algorithm takes it as a change due to perturbation and in the next iteration it changes the direction of perturbation and hence goes away from the MPP as shown in the figure. However, in this algorithm we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing in both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm [11-18].



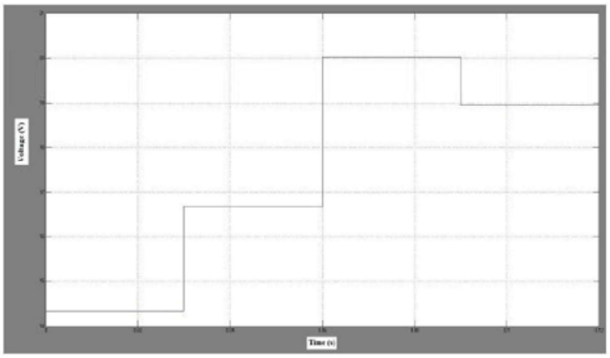
MPPT Interfacing: The controlled voltage source and the current source inverter have been used to interface the modeled panel with the rest of the system and the boost converter which are built using the Sim Power Systems module of MATLAB. is a simulation for the case where we obtain a varying voltage output. This model is used to highlight the difference between the power obtained on using an MPPT algorithm and the power obtained without using an MPPT algorithm. To compare the power output in both the cases stated above, the model is equipped with a manual switch as shown. When the switch is thrown to the left the circuit bypasses the MPPT algorithm and we obtain the desired power, voltage and current outputs through the respective scopes. Contrarily when the switch is thrown to the right, the embedded MPPT function block is included in the circuit and we obtain the desired outputs through the respective scopes [13,16].

Boost Converter: A boost converter has been used in our simulation. It finds applications in various real life scenarios like charging of battery bank, running of DC motors, solar water pumping etc. The simulation has been done for a resistive load of 300. For efficient running of a motor, we should undergo load resistance matching techniques. In the boost converter circuit, the inductor has been chosen to be 0.763 mH and the capacitance is taken to be 0.611 μF for a ripple free current.

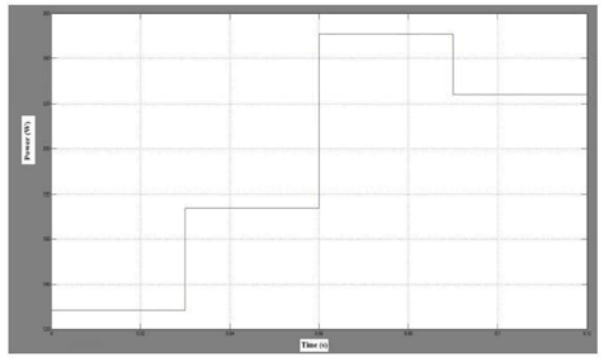
PI Controller: The system also employs a PI controller. The task of the MPPT algorithm is just to calculate the reference voltage Vref towards which the PV operating voltage should move next for obtaining maximum power output. This process is repeated periodically with a slower rate of around 1-10 samples per second. The external control loop is the PI controller, which controls the input voltage of the converter. The pulse width modulation is carried in the PWM block at a considerably faster switching frequency of 100 KHz. In our simulation, KP is taken to be 0.006 and KI is taken to be 7. A relatively high KI value ensures that the system stabilizes at a faster rate. The PI controller works towards minimizing the error between Vref and the measured voltage by varying the duty cycle through the switch [14, 15]. The switch is physically realized by using a MOSFET with the gate voltage controlled by the duty cycle.

RESULTS

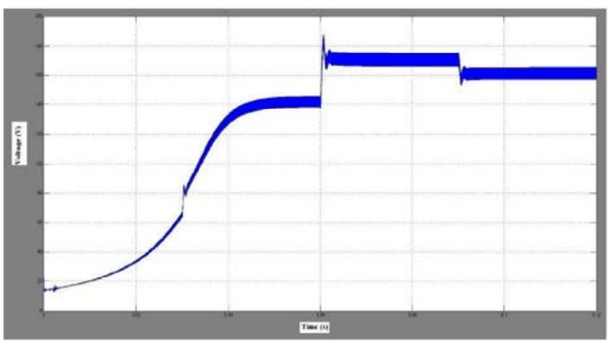
Case 1: Running the system without MPPT



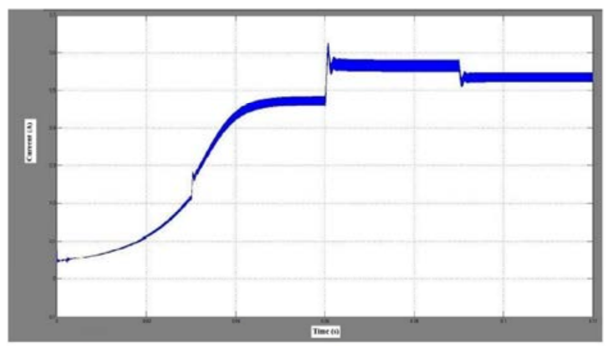
Plot of Output voltage of PV panel v/s time without MPPT



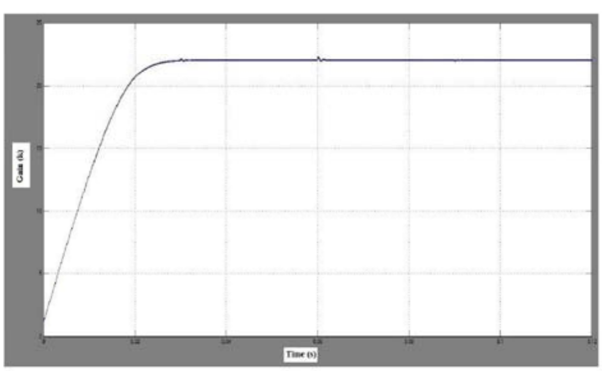
Plot of Power output of PV panel v/s time without MPPT



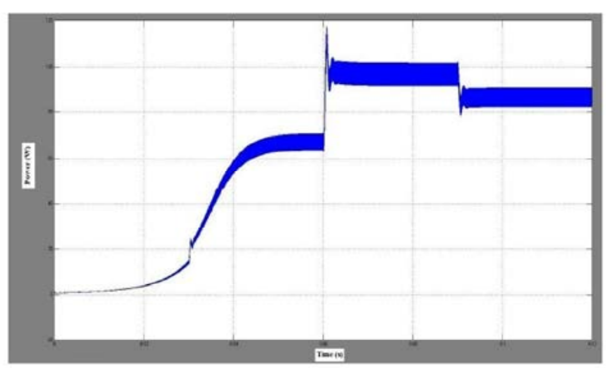
Plot of Output Voltage at load side v/s time without MPPT



Plot of Output current at load side v/s time without MPPT

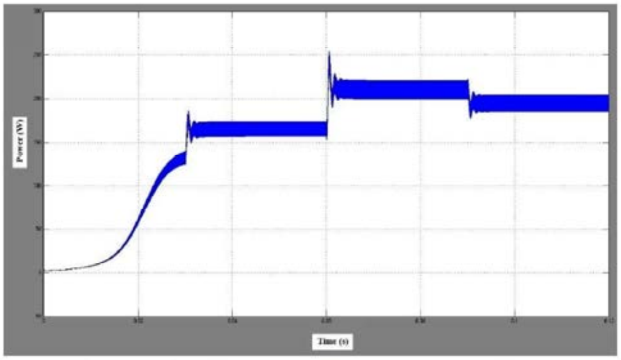


Plot of PI Control gain v/s time without MPPT

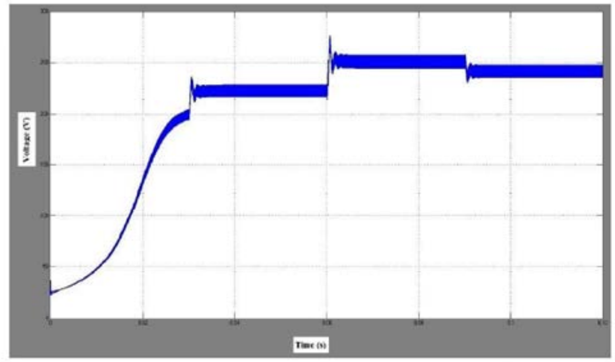


Plot of Power obtained at load side v/s time without MPPT

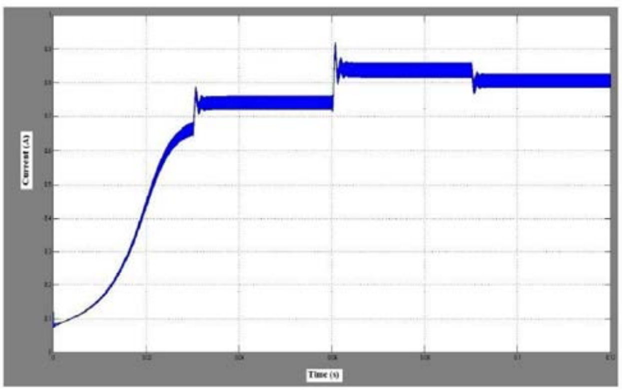
Case 2: Running the system with MPPT



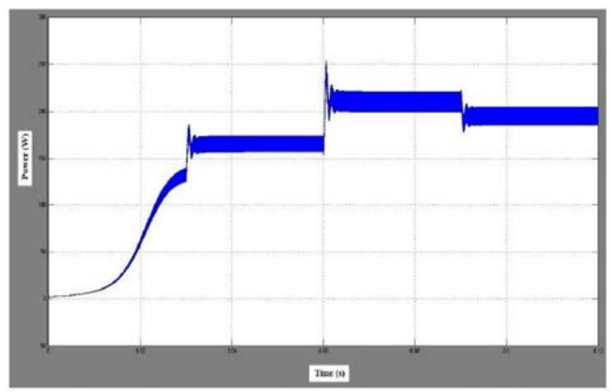
Plot of Power obtained at load side v/s time with MPPT



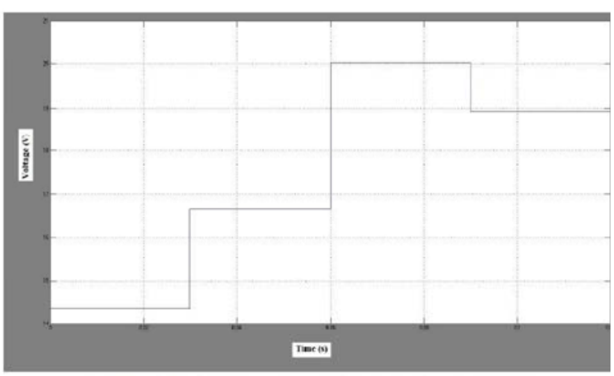
Plot of Output Voltage at load side v/s time with MPPT



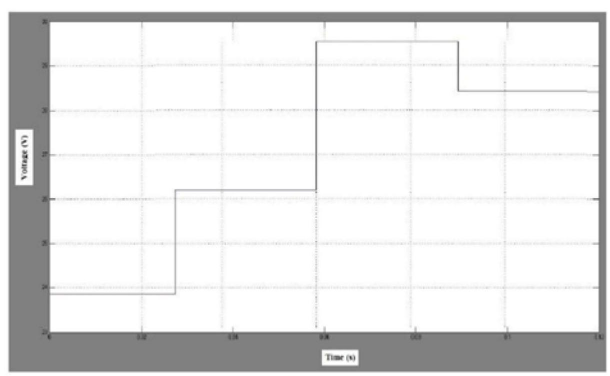
Plot of Output current at load side v/s time with MPPT



Plot of Power obtained at load side v/s time with MPPT



Plot of Output voltage of PV panel v/s time with MPPT



Plot of calculated MPPT V_{ref} voltage v/s time with MPPT

CONCLUSION

The simulation was first run with the switch on no MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load side was around 95 Watts for a solar irradiation value of 85 Watts per sq. cm. It must be noted that the PV panel generated around 250 Watts power for this level of solar irradiation. Therefore, the conversion efficiency came out to be very low. The simulation was then run with the switch on MPPT mode. This included the MPPT block in the circuit and the PI controller was fed the Vref as calculated by the P&O algorithm. Under the same irradiation conditions, the

PV panel continued to generate around 250 Watts power. In this case, however, the power obtained at the load side was found to be around 215 Watts, hus increasing the conversion efficiency of the photovoltaic system as a whole. The loss of power from the available 250 Watts generated by the PV panel can be explained by switching losses in the high frequency PWM switching circuit and the inductive and capacitive losses in the Boost Converter circuit. Therefore, it was seen that using the Perturb & Observe MPPT technique increased the efficiency of the photovoltaic system by approximately 126% from an earlier output power of around 95 Watts to an obtained output power of around 215 Watts.

REFERENCES

1. Schaefer, J., 1990. Review of photovoltaic power plant performance and economics, IEEE Trans. Energy Convers., EC-5: 232-238.
2. Femia, N., D. Granozio, G. Petrone, G. Spaguuolo and M. Vitelli, 2006. Optimized one-cycle control in photovoltaic grid connected applications, IEEE Trans. Aerosp. Electron. Syst., 42: 954-972.
3. Wu, W., N. Pongratananukul, W. Qiu, K. Rustom, T. Kasparis and I. Batarseh, 2003. DSP-based multiple peack power tracking for expandable power system, in Proc. APEC, pp: 525-530.
4. Hua, C. and C. Shen, 1998. Comparative study of peak power tracking techniques for solar storage system, in Proc. APEC, pp: 679-685.
5. Hohm, D.P. and M.E. Ropp, 2000. Comparative study of maximum power point tracking algorithms using an experimental, programmable, maximum power point track-ing test bed, in Proc. Photovoltaic Specialist Conference, pp: 1699-1702.
6. Hussein, K.H., I. Muta, T. Hoshino and M. Osakada, 1995. Maximum power point tracking: an algorithm for rapidly changing atmospheric conditions, IEE Proc.-Gener. Transm. Distrib, 142: 59-64.
7. Sun, X., W. Wu, X. Li and Q. Zhao, 2002. A research on photovoltaic energy controlling system with maximum power point tracking, in Power Conversion Conference, pp: 822-826.
8. Kottas, T.L., Y.S. Boutalis and A.D. Karlis, 2006. New maximum power point tracker for PV arrays using fuzzy controller in close cooperation with fuzzy cognitive net-work, IEEE Trans. Energy Conv., 21: 793-803.
9. Kim, I.S., M.B. Kim and M.Y. Youn, 2006. New maximum power point tracking using sliding-mode observe for estimation of solar array current in the grid-connected photovoltaic system, IEEE Trans. Ind. Electron., 53: 1027-1035.
10. Hsiao, Y.T. and C.H. Chen, 2002. Maximum power tracking for photovoltaic power system, in Proc. Industry Application Conference, pp: 1035-1040.
11. Yu, G.J., Y.S. Jung, J.Y. Choi, I. Choy, J.H. Song and G.S. Kim, 2002. A novel two-mode MPPT control algorithm based on comparative study of existing algorithms, in Proc. Photovoltaic Specialists Conference, pp: 1531-1534.
12. Noguchi, T., S. Togashi and R. Nakamoto, 2002. Short-current pulse-based maximum-power-point tracking method for multiple photovoltaic-and-converter module system, IEEE Trans. Ind. Electron., 49: 217-223.
13. Lee, D.Y., H.J. Noh, D.S. Hyun and I. Choy, 2003. An improved MPPT converter using current compensation method for small scaled PV-applications, in Proc. APEC, pp: 540-545.
14. Park, M. and I.K. Yu, 2004. A study on optimal voltage for MPPT obtained by surface temperature of solar cell, in Proc. IECON, pp: 2040-2045.
15. Takashima, T., T. Tanaka, M. Amano and Y. Ando, 2000. Maximum output control of photovoltaic (PV) array, in Proc. 35th Intersociety Energy Convers. Eng. Conf. Ex-hib., pp: 380-383.
16. De Carvalho, P.C.M., R.S.T. Pontes, D.S. Oliveira, D.B. Riffel, R.G.V. de Oliveira and S.B. Mesquita, 2004. Control method of a photovoltaic powered reverse osmosis plant without batteries based on maximum power point track-ing, in Proc. IEEE/PES Transmiss. Distrib. Conf. Expo.: Latin America, pp: 137-142.
17. Esram, T. and P.L. Chapman, 2007. Comparison of photo-voltaic array maximum power point tracking techniques, IEEE Trans. Energy Conv., 22: 439-449.
18. Balachander, K. and Dr. A. Amudha, 2015. Energy Audit and Renewable Energy System Modeling, Middle East Journal of Scientific Research, 23(7): 1305-1313.