ISSN 2321-807X
Volume 12 Number18
Journal of Advances in chemistry

A novel electrical and mechanical MPPT for Solar Photovoltaic System at any climatic condition and sudden changes in the irradiance

Dr. K. Dhayalini
Professor, Department of Electrical and Electronics Engineering,
K. Ramakrishnan College of Engineering, Thiruchirappalli, Tamilnadu, India
Email ID: dhaya2k@gmail.com, dhayalini@krce.ac.in

ABSTRACT

Maximum power point tracking (MPPT) techniques are widely used in photovoltaic (PV) systems to make the best use of the PV panel power output by tracking frequently the maximum power point (MPP) which depends on panel's temperature and on irradiant environmental conditions. The various hitches of MPPT have been addressed in different ways. But eventually towards economical implementation, the perturb and observe (P&O) maximum power point tracking algorithm is the most widely adapted method due to its ease of implementation. A drawback of P&O is that, at steady state, the operating point oscillates around the MPP giving rise to the waste of some amount of available energy; moreover, it is well known that the P&O algorithm can be confused to attain the MPP during the distinctly changing atmospheric conditions. In this paper, it is shown that, in order to extensively reduce the negative effects associated to the above drawbacks, a novel MPPT can be adopted with the use of LDR. In the same manner use of modified cylindrical panel with reflector can increase the working hours of the panel like a mechanical tracking.

Indexing terms/Keywords

MPPT, reflector based panel, modified panel, electrical with mechanical MPPT, novel MPPT

1. INTRODUCTION

Now a days, modern power generation mechanisms are gaining wide popularity around the world due to the increase in the environmental issues that are created as a result of the classical power generation methods [1] , [5]. The enormous usage of conventional energies results in considerable increase of global warming and temperature. Recently, renewable energies, especially photovoltaic (PV) energy, are considered as an emollient energy resource. It is commonly used in many applications such as water pumping systems, street signaling/lighting and power provision for houses. Such PV systems do not require special maintenance and are easy to install. They considerably ensure a durable long life without causing noise or bothering effects.

On the other hand, such PV systems are also adhered to the drawback of low conversion efficiency. Hence, optimization technique is found to be a requisite while designing a PV system. Such optimization can be achieved by extracting the maximum power output of PV systems under the unstable climatic conditions. Hence, the most widely accepted "maximum power point tracking (MPPT)" is applied to get the most power out of a solar panel through a DC to DC converter. Numerous techniques have also been proposed depending on their complexity, sensors used, convergence, setup, and in many other aspects [6]-[10].

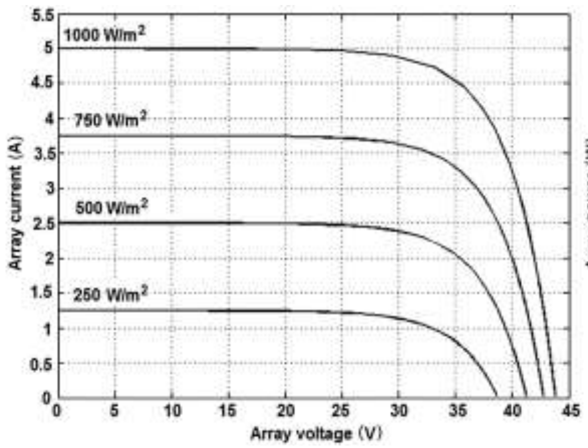

Fig. 1 Array current–voltage curve

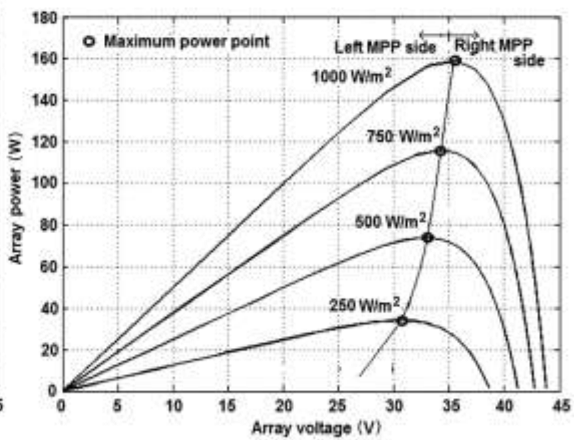

Fig. 2 Array power–voltage curve

The I-V curve and the P-V curve of the panel are shown in Figs. 1 and 2, respectively, under uniform solar radiations.

It is observed from the Fig. 2 that the panel's maximum power differs along with the solar radiation. Therefore, it is indispensable to track frequently such points.

2. MAXIMUM POWER POINT TRACKING (MPPT)

It is an electronic function that adjusts voltage / current parameters to get the most power out of a solar panel [1], [12-15].

2.1 MPPT methods

Maximum power point trackers may implement different algorithms and switch between them based on the operating conditions of the panel. Based on these conditions, we have two types of MPPT – the Electrical MPPT and the Mechanical MPPT.

Generally have two types of MPPT they are Electrical MPPT and Mechanical MPPT, in electrical MPPT optimize the panel output power, and in mechanical MPPT rotate the panel towards the sun.

2.2 Electrical MPPT

As shown in Fig.3, the electrical MPPT aims to keep the output of a solar panel, constant all of the time. Under difficult weather conditions also, the system still outputs the same current & voltage and therefore the power output remains the same as if the solar panel was receiving full solar irradiance.

Under Electrical MPPT, we have two common methods which are the perturb and observe (P&O) method, and the incremental conductance method.

The P&O method is popular due to its ease of implementation. It functions by creating a perturbation in the voltage, which results in variation in the array power. Contrarily, the rapid changes in the solar irradiance level can cause serious problem in the P&O algorithm behavior.

On the other hand, the incremental conductance method computes the maximum power point by comparing the incremental conductance with the panel conductance. This method can track changing conditions more rapidly than the perturb and observe method. It has a higher level of accuracy with good flexibility to rapidly varying environmental factors [6]. However, it has more difficulty in designing the hardware towards implementation.

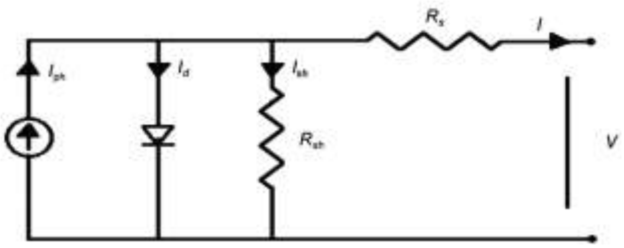

Fig. 3 Equivalent circuit of a solar cell

The output current of the PV cell is given by

$$I = I_{ph} - I_d = I_{ph} - I_o\left(\exp\left(\frac{V}{V_t}\right) - 1\right) \tag{1}$$

where I_{ph} is the photocurrent, I_d is the junction current, I_o is the reverse saturation current, and V_t is the thermal voltage.

2.3 Mechanical MPPT

Mechanical MPPT is also one of the methods that improve the panel efficiency. Mechanical tracking looks at the position of the sun in the sky relative to the location of the solar panel, from dawn until dusk. A mechanical tracker twists and tilts the panel so it is in the best position and at 90°, to the sun all the time. As shown in Fig. 4, this result in the solar panel having the maximum possible solar irradiation available to it which results in the solar panel performing very efficiently and outputting the maximum possible power all of the time.

But in this method, we have some of the drawbacks to rotate the panel; it needs critical control system and extra power to operate the control drives.

3. PROPOSED MODEL INCORPORATING ELECTRICAL & MECHANICAL MPPT TECHNIQUES

According to the above discussion, electrical and mechanical MPPT have some of their own difficulties towards practical implementation. Hence, a novel method has been proposed this uses light sensor and modified panel. The light sensor (LDR) gives the variable resistance based on the light falling on it. Depending on the variable resistance the microcontroller operates the MPPT driver circuit.

The proposed model as in Fig. 5 and Fig. 6, works on the basic principle of voltage variation. Since the microcontroller cannot operate directly with the resistance value, it has to be converted into an equivalent voltage parameter. Fundamentally, when the variable resistance is high, then the voltage value will be low and vice versa. Such voltage variation is received by the microcontroller for operating the MPPT driver circuit.

The main drawback of the P&O algorithm is the oscillation of the power output value around the MP point, which is being avoided by our proposed method wherein the microcontroller effectively operates the driver circuit at any of the extreme voltage values.

Fig. 4 Normal 100 watts panel

Table. 1 shows the comparison of normal and modified panel output against LDR resistance at frequent time intervals. This forms the underlying concept of the novel MPPT. Depending on the LDR output, the microcontroller fixes the operating point of the converter driver circuit, which in turn operates the DC to DC converter at the maximum power point of the panel.

Table. 1 LDR resistance at various light intensity

Time	LDR Resistance (ohms)	Normal 100 Watts panel Maximum output (Watts)	Modified 100 Watts panel maximum output (Watts)
06.30 AM	1027	50	46
07.00 AM	920	52	50
07.30 AM	840	52	51
08.00 AM	760	53	60
08.30 AM	680	53	78
09.00 AM	600	57	82
09.30 AM	520	62	83
10.00 AM	440	65	88
10.30 AM	360	70	89
11.00 AM	280	75	92
11.30 AM	200	81	95
12.00 PM	125	86	96
12.30 PM	120	102	101
01.00 PM	135	101	101.5
01.30 PM	180	101	102
02.00 PM	220	95	99

02.30 PM	300	84	96
03.00 PM	480	76	95
03.30 PM	560	72	92
04.00 PM	640	65	89
04.30 PM	720	58	81
05.00 PM	800	56	71
05.30 PM	880	55	65
6.00 PM	1030	54	55

Table. 2 The rated electrical specification of the photovoltaic panel parameters of solar array

Voc	21.5 V
Isc	06.55 A
Vmp	17.10 V
Imp	05.85 A
Max. Power	100.0 W

4. DESIGN OF MODIFIED PANEL

Instead of mechanical tracking applied in the prevailed methods, a modified panel is used to increase the power output. While designing the modified panel and selecting the reflector, two points have to be considered:

a) The panel diameter and

b) Size of the reflector.

The size of the reflector is primarily based on the modified panel diameter and also on the panel length, since the reflector reflects the sun light to the panel properly; the reflector reflects the sunlight at morning 08.45 hrs to 12.00 hrs and afternoon 01.30 hrs to 4.30 hrs. Hence the reflector height has to be chosen depending on these two factors, and also carefully fixed the reflector such that the shadow should not fall on the panel. To neglect the fall of shadow, fixed the reflectors on sides of the panel with some angle, so that shadow will not fall on the panel as per the reflector rule [2-4, 11]. Table. 2 shows the readings of fixed and modified panel DC output.

Fig. 5 Modified structure 100 Watts panel

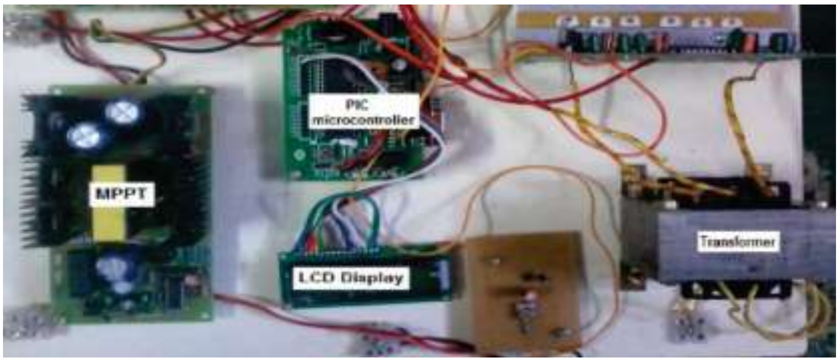

Fig. 6 Experimental setup

5. EXPERIMENTAL SETUP RESULTS

After implementing the proposed model, careful observations are made at frequent time intervals viz.8.45am, 9.45am, 10.45am, 11.45am, 12.45pm, 1.45pm, 2.45pm, 3.45pm, 4.30pm. Readings taken at 8.45am are shown in Table .3, in which with fixed panel the maximum power is 53.3W and when modified with the reflector panel it is 78W. Table.4 shows the readings taken at 9.45am in which the maximum power with fixed panel is 61.77W and when modified with reflector panel it is 82.92W. Readings taken at 10.45am is depicted in Table .5. The readings taken at 10.45am shows that the maximum power with fixed panel is 69.11W and that with reflector panel are 89.05W. Table .6 shows the readings taken at 11.45am. From the readings it is clear that with fixed panel the maximum power is 81.04W and with reflector panel it is 95.71W. Readings taken at 12.45pm, 1.45pm, 2.45pm, 3.45pm and 4.30pm are shown in Tables 7, 8,9,10 and 11 respectively. During 12.45pm and 1.45pm the maximum power with fixed panel are 103.12W and 101.67W and with reflector panel it is 101.78W. During this period only the power is maximum relatively. At 2.45pm, 3.45pm and 4.30pm the maximum power started to reduce as 83.96W, 72.18W and 57.99W with fixed panel and 96.54W, 92.40W and 80.82W with reflector panel respectively.

Maximum power voltage and current outputs of normal and modified reflector panel are shown in Fig. 7 and Fig. 8. From the figures it is clear that the voltage and current outputs are maximum during 12.45pm to 1.45pm. Fig. 9 shows the maximum power output of the two cases. Fig.10 depicts the power generated by the PV array and Fig. 11 shows the proposed electrical MPPT output.

Table. 3 Readings taken at 8.45 AM

Reading comparison at 8.45 AM		
Output	Fixed Panel	Modified with reflector panel
Voc	19 V	20.5 V
Isc	4.5 A	5.2 A
Vmp	13 V	15 V
Imp	4.1 A	5.2 A
Max. Power	53.3 W	78 W

Table. 4 Readings taken at 9.45 AM

Reading comparison at 9.45 AM		
Output	Fixed Panel	Modified with reflector panel
Voc	19.7 V	21.1 V
Isc	4.54 A	5.32 A
Vmp	14.2 V	15.5 V
Imp	4.35 A	05.35 A
Max. Power	61.77 W	82.92 W

Table. 5 Readings taken at 10.45 AM

Reading comparison at 10.45 AM		
Output	Fixed Panel	Modified with reflector panel
Voc	20.1 V	21.5 V
Isc	4.62 A	5.8 A
Vmp	14.8 V	16.4 V
Imp	4.67 A	05.43 A
Max. Power	69.11 W	89.05 W

Table. 6 Readings taken at 11.45 AM

Reading comparison at 11.45 AM		
Output	Fixed Panel	Modified with reflector panel
Voc	21.1 V	22.2 V
Isc	5.82 A	6.5 A
Vmp	15.83 V	17.0 V
Imp	5.12 A	5.63 A
Max. Power	81.04 W	95.71 W

Table. 7 Readings taken at 12.45 PM

Reading comparison at 12.45 PM		
Output	Fixed Panel	Modified with reflector panel
Voc	22.5 V	22.52 V
Isc	6.73 A	6.72 A
Vmp	17.37 V	17.34 V
Imp	5.88 A	05.87 A
Max. Power	102. 13W	101.78 W

Table. 8 Readings taken at 1.45 PM

Reading comparison at 1.45 PM		
Output	Fixed Panel	Modified with reflector panel
Voc	22.49 V	22.51 V
Isc	06.71 A	06.74 A
Vmp	17.35 V	17.34 V
Imp	5.86 A	5.87 A
Max. Power	101. 67W	101.78W

Table. 9 Readings taken at 2.45 PM

Reading comparison at 2.45 PM		
Output	Fixed Panel	Modified with reflector panel
Voc	21.40 V	21.41 V
Isc	6.23 A	6.51 A
Vmp	16.24 V	17.21 V
Imp	05.17 A	05.61 A
Max. Power	83.96W	96.54 W

Table. 10 Readings taken at 3.45 PM

Reading comparison at 3.45 PM		
Output	Fixed Panel	Modified with reflector panel
Voc	21.38 V	21.12 V
Isc	06.03 A	6.32 A
Vmp	15.01 V	16.74 V
Imp	4.81 A	5.52 A
Max. Power	72.18W	92.40 W

Table. 11 Readings taken at 4.30 PM

Reading comparison at 4.30 PM		
Output	Fixed Panel	Modified with reflector panel
Voc	19.21 V	21.01 V
Isc	4.92 A	5.89 A
Vmp	14.11 V	16.10 V
Imp	04.11 A	05.02 A
Max. Power	57.99W	80.82 W

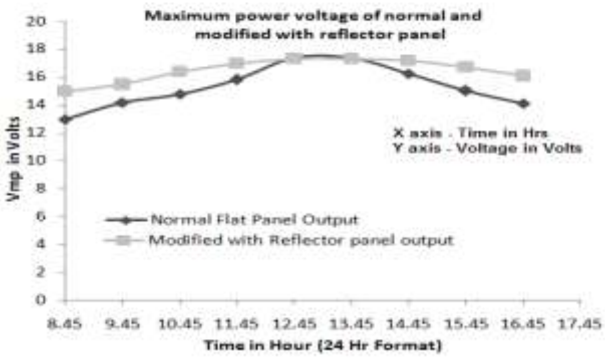

Fig. 7 Maximum power voltage output of normal and modified panel

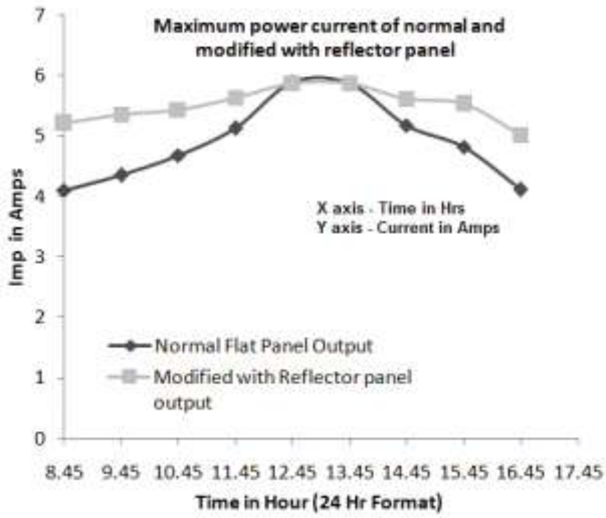

Fig. 8 Maximum power current output of normal and modified panel

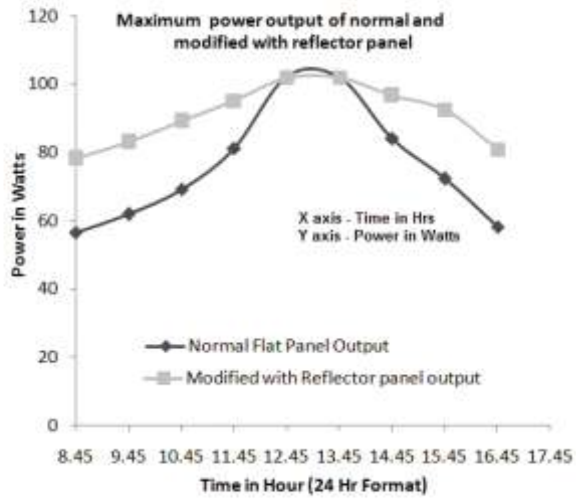

Fig. 9 Maximum power output of normal and modified Panel

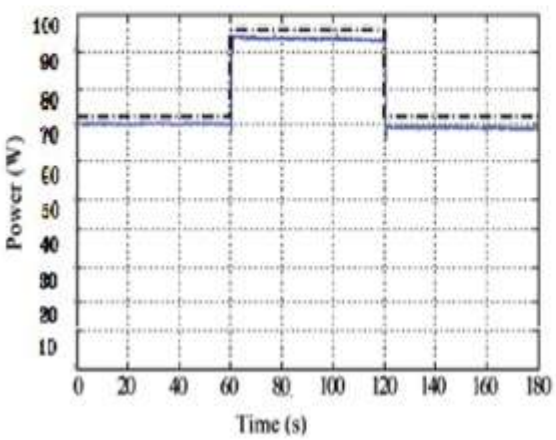

Fig. 10 Power generated by the PV array

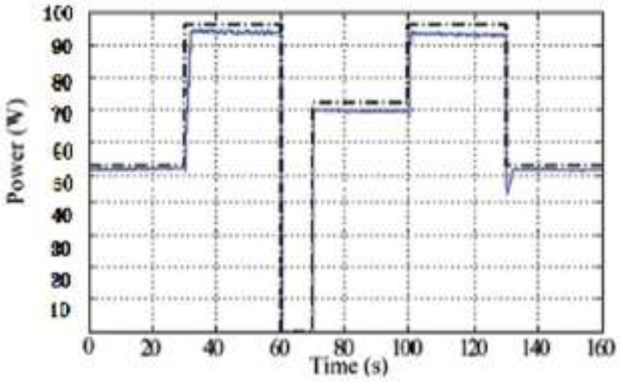

Fig. 11 Proposed Electrical MPPT Output

6. CONCLUSION

This paper develops an optimal MPPT method that has been tested under varying climatic conditions. In the prevailing system, tracking the panel towards the sun is one of the challenging phenomenons faced. This drawback is considerably abridged in the proposed system through our novel techniques. From the above experimental results, it has been keenly observed that a conventional 100 watts fixed panel gives an optimum power of 5 to 5½ hours per day, whereas a modified cylindrical panel with reflector gives an optimum power of about approximately 8 hours per day. Hence the same hundred watts solar cell can produce additional output for the same day. As in the existing system adopting electrical MPPT, finding the maximum power point at sudden environmental changes is a crucial task and it consumes more time to find it. This drawback is also rectified in the proposed system since the microcontroller functions on the variable resistance arrived at by the LDR output, for operating the MPPT driver circuit. The main advantage of this system is that there is no intervention of a separate sun tracking system specifically for tracking the sun which also includes a considerable reduction of power wastages. Such system does not require a continuous maintenance also. Hence this system can easily be adopted by the people even in rural areas.

7. REFERENCES

1. Khaligh, A.; Ona, O. C. Energy harvesting: solar, wind, and ocean energy conversion systems. / Taylor and Francis Group, LLC, 2010.

2. Fraasa, L.; Averya, J.; Minkina, L.; Maxeyb, C.; Gehlb, T.; Hurtc, R.; Boehmc, R. Performance of 3-Sun Mirror Modules on Sun Tracking Carousels on Flat Roof Buildings. // High and Low Concentration for Solar Electric Applications III, edited by Martha Symko-Davies, Proc. of SPIE Vol. 7043, 704305, (2008). DOI: 10.1117/12.793179

3. Rizk J., Nagrial M. H., "Impact of Reflectors on Solar Energy Systems", World Academy of Science, Engineering and Technology. Rome, Italy, 2008.

4. Antara D. A., Robiul I. S. and Isteaque A., "Performance Improvement of PV Solar System by Diffused Reflection" Technical Report, Department of Electrical and Electronics Engineering, BRAC University, Dhaka, Bangladesh, 2010.

5. E. Koutroulis, K. Kalaitzakis, and N. C. Voulgaris, "Development of a microcontroller-based, photovoltaic maximum power point tracking control system," IEEE Trans. Power Electron., vol. 16, no. 1, pp. 46–54, Jan. 2001.

6. T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449, June. 2007.

7. N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963–973, July. 2005.

8. D. Sera, R. Teodorescu, J. Hantschel, and M. Knoll, "Optimized maximum power point tracker for fast-changing environmental conditions," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2629–2637, July. 2008.

9. L. Cristaldi, M. Faifer, M. Rossi, and S. Toscani, "An improved model based maximum power point tracker for photovoltaic panel s," IEEE Trans. Instrum. Meas., vol. 63, no. 1, pp. 63–71, Jan. 2014.

10. Y. Yusof, S. H. Sayuti, M. Abdul Latif, and M. Z. Che Wanik, "Modeling and simulation of maximum power point tracker for photovoltaic system," in Proc. Nat. Power Energy Conf. (PECon), Kuala Lumpur, Malaysia, 2004, pp. 88-93.

11. Krishnan S., Sathyasekar K., "Modified Structure and Reflector Based Solar Photovoltaic System for Optimization of Solar Energy" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.46 – 2015.

12. Sathish Kumar Kollimalla, Mahesh Kumar Mishra, "Variable Perturbation Size Adaptive P&O MPPT Algorithm for Sudden Changes in Irradiance" IEEE Transactions on Sustainable Energy, Vol. 5, No. 3, July 2014.

13. Sathish Kumar Kollimalla, Mahesh Kumar Mishra, “A Novel Adaptive P&O MPPT Algorithm Considering Sudden Changes in the Irradiance” IEEE Transactions on Energy Conversion, vol. 29, no. 3, September 2014.

14. Ali Chikh, Ambrish Chandra, “An Optimal Maximum Power Point Tracking Algorithm for PV Systems with Climatic Parameters Estimation” IEEE Transactions on Sustainable Energy, Vol. 6, No. 2, April 2015.

15. http://website www.mrsolar.com /content/pdf/Solar tech/

Author’ biography with Photo

K. Dhayalini received her B.E. (Distn.) degree in Electrical and Electronics Engineering from Alagappa Chettiar College of Engineering and Technology, Karaikudi, India in the year 1992 and received her M.E. (Distn.) degree in Power Systems from the Regional Engineering College (National Institute of Technology), Tiruchirappalli, India in 2000. She received her Ph.D degree in Power Systems in the faculty of Electrical Engineering from Anna University, Chennai, India. Currently she is working as Professor in the department of Electrical & Electronics Engineering at K. Ramakrishnan College of Engineering , Tiruchirappalli, Tamil Nadu, India. She published technical papers in International & National Journals and Conferences. Her areas of interest are power system optimization, renewable energy applications, power system operation and control and soft computing techniques. She is a life member of Indian Society for Technical Education (ISTE).