Efficiency of Photovoltaic System for DC Loads

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Abstract: The use of power electronics converters plays a key role in Solar PV based renewable energy system. The MPPT (Maximum Power Point Tracking) along with power electronics converters makes solar PV based system efficient. The objective of this paper is to produce a study in terms of efficiency with DC load for solar PV system. The simulation study is done using PSIM simulation software. A comparison table of the result is provided. Result shows that MPPT plays and important role in getting the efficient performance.

Keywords: MPPT, Solar PV, PSIM, Buck

I. INTRODUCTION

As the advances in Science and Technology added a lot of comfort in the life of common people. The kind of comfort enjoyed by the common people of today's world was not available in the life of King's of few centuries ago. Energy and its utilization plays a pivotal role in giving this comfort to the common people. In order to maintain this comfort level, the availability of energy and its efficient utilization is required. With the continuous utilization of non-renewable energy sources, there are growing concerns of energy crisis and a threat to maintain today's comfort level. To overcome this threat, it has become the necessity to utilize the renewable energy sources in efficient ways.Solar energy is considered as the most viable renewable energy source due to its natural availability in abundance. Photovoltaic (PV) is used to trap the solar energy and convert it in primary form of electrical energy. PV is emerging as a power resource, steadily becoming more affordable and proving to be more reliable. PV power promises a brighter, cleaner future for us and for generations to come. In the early 1950s, PV cells were developed as a spinoff of transistor technology. Very thin layers of pure silicon are impregnated with tiny amounts of other elements; when exposed to sunlight, small amount of electricity are produced. According to expertise the energy obtained from PVs will become the most important alternative energy source until 2040 [1-3]. The power produced by PV is DC and is not constant depending on the atmospheric conditions. Power electronics based converters are used to get the constant output DC power from PVs. In the real world, the AC load is more common than DC load. So after getting the DC power, a power electronics based inverter is used to invert DC power to AC power. For the end user power electronics plays fundamental role in developing efficient and reliable power converters [4-8]. In today's world DC load are becoming increasingly popular, like charging of Cell phones, laptops etc. PVs can be used along with efficient and reliable power electronics based converters to give DC power to these loads [5].

As the output power of PVs is variable depending on the atmospheric condition. Maximum power point tracking (MPPT) algorithm is used to get the maximum output power from PVs in all the working conditions. Commonly MPPT algorithm is used along with the switching of power electronics based DC-DC converters. Various types of MPPT algorithm is proposed [9-13].

In this paper a brief summary of various power electronics based converters are discussed used in PV energy conversion. Simulation study of PV energy conversion system for bucktype dc-dc converter with and without MPPT is done. The variation of output power of PV under various operating conditions is studied and the efficiency with DC load as a function of sun light intensity, ambient temperature and load variation with and without MPPT are given and discussed.

Section II of this paper gives brief working of PV energy conversion for AC and DC load. Section III gives the brief review of popular power electronics converters used in PV energy conversion. Section IV gives the simulation scheme along with results followed by discussion. Section V gives the conclusion

II. WORKING OF PV ENERGY CONVERSION SYSTEM

A. For AC Loads

As shown in Fig 1, PV Cell module is connected to DC-DC converter for getting the constant DC output. It is then inverted into AC by using DC-AC converter to get connected with AC load.

B. For DC Loads

As shown in Fig. 2, PV cell module is connected to DC-DC converter for getting the constant DC output and then it is connected to DC load.

Commonly in both the cases MPPT algorithm is implemented along with the switching scheme of DC-DC converter.

III. POWER ELECTRONICS BASED CONVERTERS

Various types of power electronics based converters are proposed and used to get the efficient and reliable PV energy conversion system. The commonly used converters are drawn here. Fig 3 shows the buck type converter: a)- Only buck converter is sufficient for DC loads, b)- While for AC loads, a single phase inverter circuit is connected to the output of DC-DC buck converter followed by AC loads. Fig. 4 is the schematic of boost type converter for DC and for AC load as well. Similarly Fig. 5 is the schematic of Buck- Boost Converter for both DC and AC load.In all the above schemes MPPT algorithm is implemented along with the Switching scheme of DC-DC converter.

IV. SIMULATION SCHEME AND RESULTS

PSIM Simulation software is used for simulation study. Physical model of Solar panel is used. Schematic of basic simulation circuit is shown in Fig. 6.The output current and voltage of the PV panel is measured using ammeter Icell and the voltmeter Vcell respectively. The output current and voltage is sensed using current and voltage sensors. These sensed output current and voltage is multiplied to get the out power of PV panel. The variation of output current of PV module is plotted and studied with the variation of ambient temperature keeping Sun light radiation constant. The variation of output current is plotted and studied with the variation of solar radiation keeping the ambient temperature constant.

The simulation result for the variation of PV panel output current Icell, with the variation in ambient temperature keeping solar light intensity constant is plotted in Fig. 7. The result for variation of Icell with the variation in solar light intensity, keeping ambient temperature constant is plotted in Fig. 8. It is observed from Fig. 7 that Icell started to fall from its maximum value at lower Vcell values, if the ambient temperature is increased. It is also observed from Fig. 8 that Icell has higher values for high solar light intensity but started to fall from its maximum value at lower values of Vcell. While at low light intensity, Icell value is maintained constant for longer duration i.e. started to fall from its maximum value at higher values of Vcell.

The simulation result for the variation of PV panel output power, with the variation in ambient temperature keeping the solar light intensity constant is plotted in Fig. 9. The results for the variation of PV panel output power, with the variation in solar light intensity, keeping ambient temperature constant is plotted in Fig. 10. From the results of Fig. 9, it is observed that maximum power point is achieved at low ambient temperature. And from the result of Fig. 10, it is observed that the maximum power point is achieved at higher values of solar light intensity.

Figure.11 is the schematic of DC-DC buck converter connected with PV panel for DC load without MPPT. Figure.12 is the schematic of DC-DC buck converter connected with PV panel for DC load with MPPT.Figure.13 is the simulated result of the voltage buck conversion .

In both the cases i.e. buck converter with and without MPPT, the input power is measured by multiplying the voltage Vcell and Icell. And Output power is measured by multiplying the output Voltage and current of buck converter. The efficiency is calculated by dividing the output power with input.

Three variables are chosen to measure the efficiency i.e. with MPPT and without MPPT:

1)- By Varying the Sun Light Intensity keeping the ambient temperature and load constant.
2)- By Varying the ambient temperature, keeping the sun light intensity and load constant.
3)- By varying the load, keeping the sun light intensity and ambient temperature constant.

The result of efficiency measurement is listed in Table.1 and II.

As the measured result of efficiency shows efficiency increases with the implementation of MPPT. Also, the efficiency with MPPT is higher with high load condition and lower with low load condition. It is due to the reason that MPPT has fixed the output power of PV panel.

V. FIGURES AND TABLES

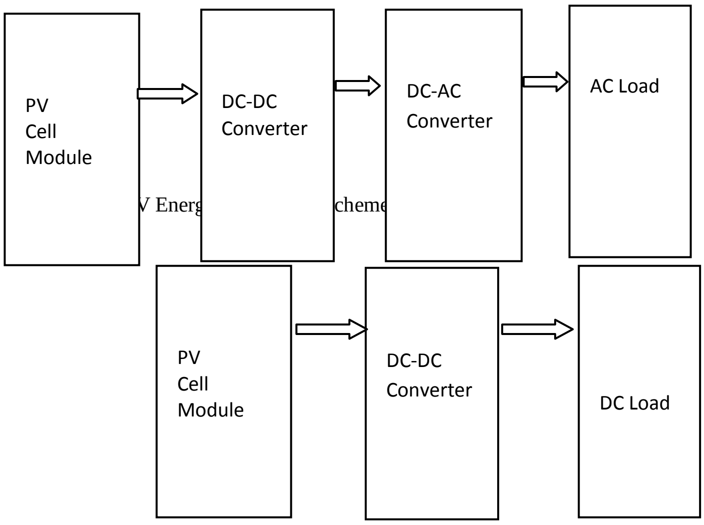
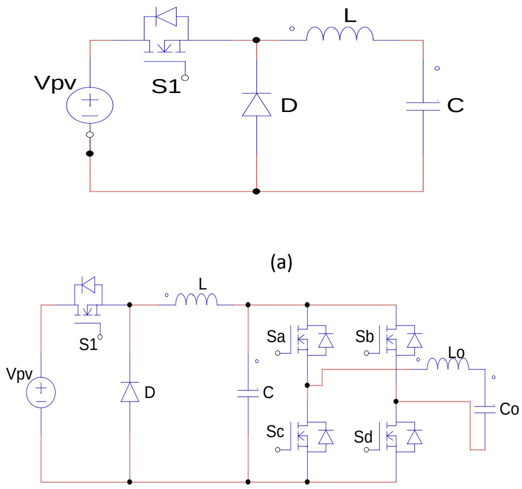


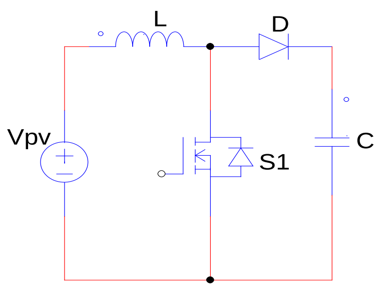
Figure 2: PV Energy Conversion Scheme for DC Load.



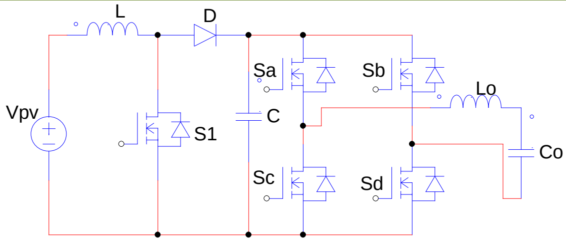
(a)

(b)

Figure 3: Buck Converter for (a)- DC Load and (b)- AC Load.

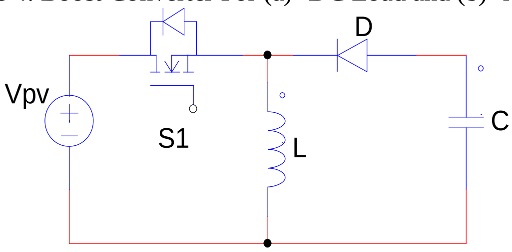


(a)



(b)

Figure 4: Boost Converter For (a)- DC Load and (b)- AC Load.



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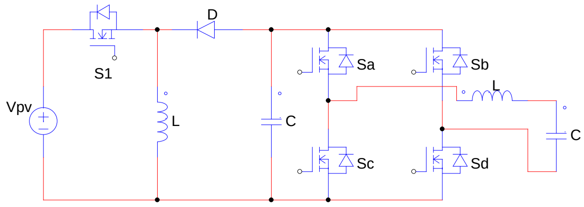

(b)

Figure 5: Buck- Boost Converter For (e)- DC Load and (f)-AC Load.

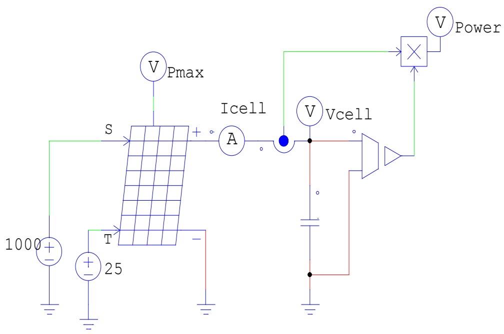

Figure 6: Schematic of Simulation Circuit

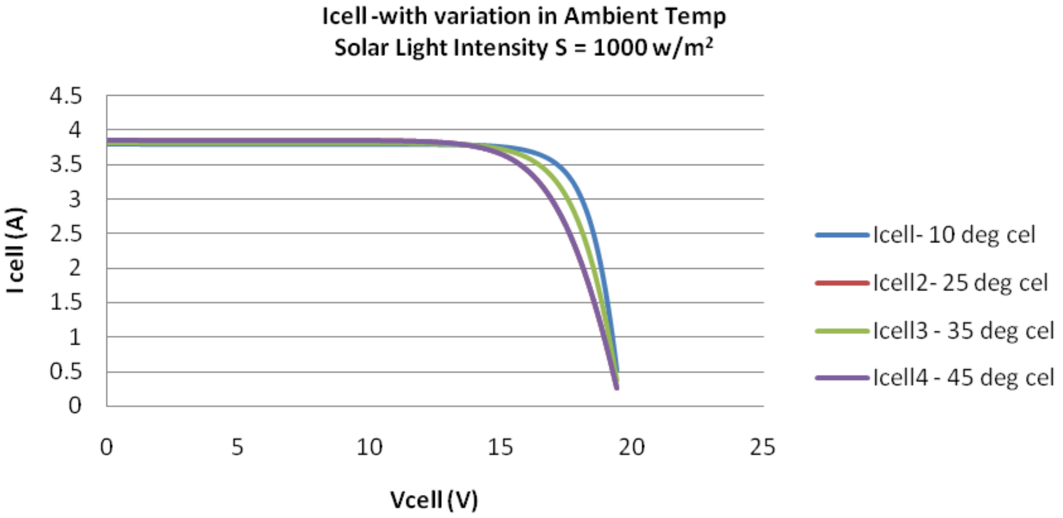

Figure 7: Simulation Results- Variation of PV panel output current with the variation in ambient temperature, keeping the Solar Light Intensity constant.

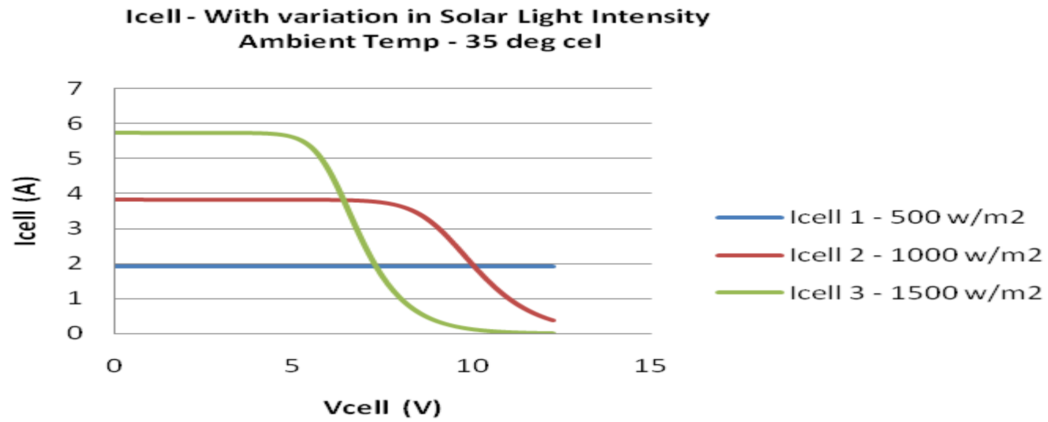

Figure 8: Simulation Results- Variation of PV panel output current with the variation of Solar Light Intensity, keeping the Ambient Temperature constant

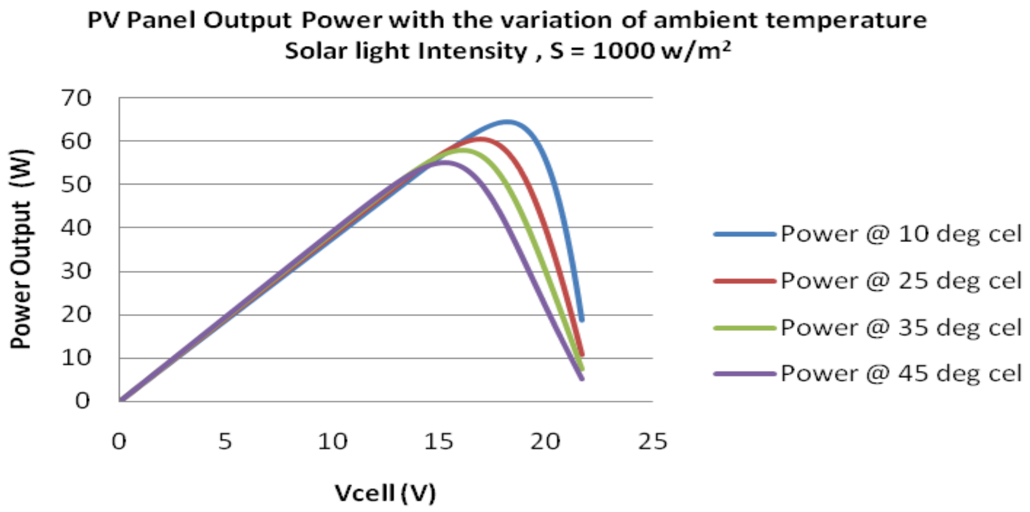

Figure 9: Simulation Results- Variation of PV panel output power with the variation of Ambient Temperature, keeping the Solar LightIntensity constant.

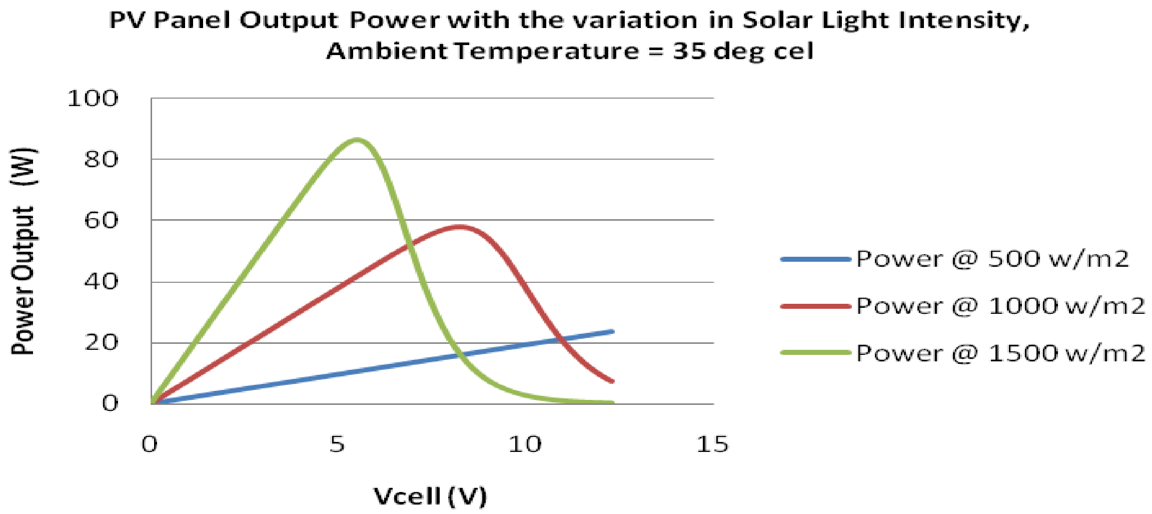

Figure 10: Simulation Results- Variation of PV panel output power with the variation of Solar Light Intensity keeping the AmbientTemperature constant.

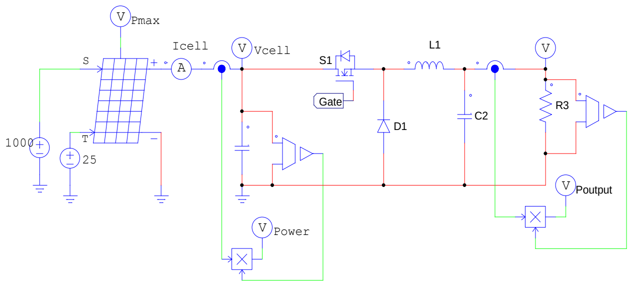

Figure 11: Simulation Scheme: Schematic of Buck DC-DC Converter without MPPT to measure the efficiency for DC loads.

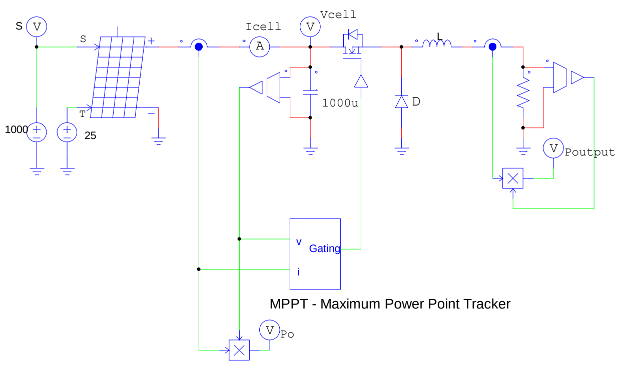

Figure 12: Simulation Scheme: Schematic of Buck DC-DC Converter with MPPT to measure the efficiency for DC loads.

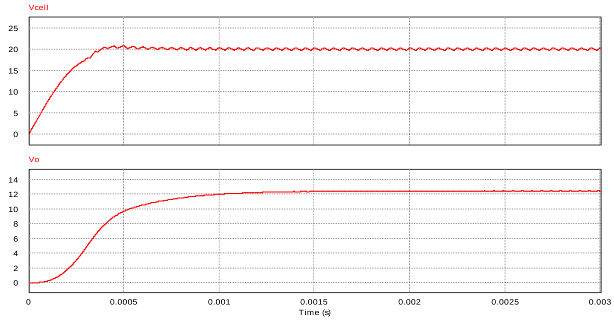

Figure 13: Simulation Result: Input and Output Voltage of Buck DC-DC Converter without MPPT to measure the efficiency for DCloads.

TABLE I. EFFICIENCY OF BUCK TYPE PV POWER CONVERSION WITHOUT MPPT

S.No.	Sun Light Intensity (w/m^2)	Ambient Temperature (degcel)	Load (Ohm)	Efficiency (%)
1	500	25	5	55.8
2	1000	25	5	57
3	1500	25	5	59
4	1000	35	5	53
5	1000	45	5	51
6	1000	25	10	58
7	1000	25	15	58

TABLE II. EFFICIENCY OF BUCK TYPE PV POWER CONVERSION WITH MPPT

S.No.	Sun Light Intensity (w/m^2)	Ambient Temperature (degcel)	Load (Ohm)	Efficiency (%)
1	500	25	5	78
2	1000	25	5	79
3	1500	25	5	81
4	1000	35	5	60
5	1000	45	5	58
6	1000	25	10	62
7	1000	25	15	60

VI. CONCLUSION

The use of DC load has become increasingly popular and PV energy conversion is considered as the important energy conversion method in the future. The objective of this paper work was to provide a study of Solar PV system with power electronics converters in terms of efficiency and MPPT. The study shows that efficiency has increased with MPPT. The future scope of this work is to implement the same with AC and DC load both.

REFERENCES

[1] De Brito, M.A.G.; Sampaio, L.P.; Junior, L.G.; Canesin, C.A., "Research on photovoltaics: Review, trends andperspectives",IEEE Power Electronics Conference (COBEP),Brazil, 2011, pp. 531 – 537.

[2] O. Stalter, et al. " Advanced Solar Power Electronics", in Proc. Of International Symposium on Power Semiconductor Devices & ICs, vol. 22, 2010, pp. 3-10.

[3] Spanuolo, et al. " Renewable Energy Operation and Conversion Schemes", IEEE Trans on Industrial Electronics, vol.4, no.1, 2010, pp. 38-51.

[4] Behrouzian, E.; Tabesh, A.; Bahrainian, F.; Zamani, A. " Power electronics for photovoltaic energy system of an Oceanographic buoy", IEEE Applied Power Electronics Collegium (IAPEC), 2011, pp. 1-4.

[5] Siwakoti, Y.P.; Chhetri, B.B.; Adhikary, B.; " Microcontroller based intelligent DC/DC converter to track Maximum Power Point for solar photovoltaic module", IEEE Conf on innovative technologies for an efficient and reliable Electricity supply (CITRES) 2010, pp. 94-101.

[6] Adhikari, N.; Singh, B.; Vyas, A.L., " Performance evaluation of a low power solar-PV energy system with SEPIC converter", IEEE Conf. Power Electronics and Drive Systems (PEDS), 2011, pp. 763-769.

[7] Junior, L.G.; de Brito, M.A.G.; Sampaio, L.P.; Canesin, C.A., " Evaluation of integrated inverter topologies for low power PV systems", IEEE Conf. Clean Electrical Power (ICCEP), 2011, pp. 35- 39.

[8] Spagnuolo, G.; Petrone, G.; Araujo, S.V.; Cecati, C.; Friis-Madsen, E.; Gubia, E.; Hissel, D.; Jasinski, M.; Knapp, W.; Liserre, M.; Rodriguez, P.;Teodorescu,R.;Zacharias,P.,"Renewable Energy Operation and ConversionSchemes: A Summary of Discussions During the Seminar on Renewable Energy Systems", IEEE Industrial Electronics Magazine,
Vol: 4 , Issue: 1, 2010, pp. 38 – 51.

[9] Faranda,R.;Leva,S.;Maugeri,V.,"MPPT techniques for PV Systems: Energetic and costcomparison", IEEE Conference Power and Energy Society General Meeting - Conversion andDelivery of Electrical Energy in the 21st Century, pp. 1 – 6, 2008.

[10] De Brito, M.A.G.; Sampaio, L.P.; Junior, L.G.; Canesin, C.A., "Evaluation of MPPT techniques for photovoltaicapplications", IEEE International Symposium on Industrial Electronics (ISIE), pp. 1039 – 1044, 2011.

[11] Brito, M.; Galotto, L.; Sampaio, L.; Melo, G.; Canesin, C., "Evaluation of the Main MPPT Techniques for Photovoltaic Applications",IEEE Tran on Industrial Electronics, vol: PP , Issue: 99 , pp. 1 - 1, 2012.

[12] A. Haque, "Maximum Power Point Tracking (MPPT) Scheme for Solar Photovoltaic System," *Energy Technol. Policy*, vol. 1, no. 1, pp. 115–122, 2014.

[13] Zaheerudin, Sukumar and M. Ahteshamul, "Performance evaluation of modified perturb & observe maximum power point tracker for solar PV system," *Int. J. Syst. Assur. Eng. Manag.*, vol. 7, no. 1, pp. 229–238, 2015.

