The International Journal of
Materials and Engineering Technology

ISSN :
TIJMET, Vol. 01 (01), 2018, (7 pages) ID: 180101003
Type of the Paper: Article
Received: 26.06.2018; Accepted: 24.08.2018

INCREASING ENERGY EFFICIENCY FOR INTEGRATING SMALL SCALE PV POWER GENERATION TO GRID SYSTEM

MEHMET ALİ ÖZÇELİK*[1]

[1] School of Technical Science, Electric and Energy Department, Gaziantep University, Gaziantep, TURKEY
E-mail address: ozcelik@gantep.edu.tr

Abstract

The use of renewable energy resources is increasing day by day, and the importance of solar energy is increasing and photovoltaic energy conversion is taking place in micro-networks. Therefore, it is important to take power at high level in photovoltaic systems. The electrical energy produced by the PV panels varies depending on the radiation and temperature, and in some cases this energy is not sufficient for the maximum power transfer of the micro-inverter. The maximum power transfer level of the inverter is increased by providing battery support near the input voltage at which the micro-inverter can deliver maximum power. The output power of the PV system is constantly measured by means of sensors, and the inverter input voltage range near enough to the gentle is kept at a certain level by the microprocessor and the proposed algorithm and PV system efficiency has been increased this way.

Keywords: PV system, micro grid, energy efficiency, micro inverter, smart system.

1.Introduction

Due to factors such as increasing world population, the exhaustion of fossil-based energy sources and global warming, the request of solar/wind energy system has been increasing [1,2]. The building-integrated use of these energies in meeting the energy demand is getting common [3] and it bears benefits for environment, economy and social life [4]. While wind and solar energies have an important place among renewable energy sources, the solar energy systems have grown 20-25% for the last 20 years and the growth is mostly in grid-connected applications [5,6]. Figure 1 shows the levels of radiation falling on world countries and the figure indicates that solar energy is abundant [7,8]. PV panels absorb part of the irradiation falling on it and convert the other part into direct current electricity [9]. The solar radiation falling on PV panels in relation to the heat is showing in Fig.2 a non-linear characteristic [10]. Thus, due to their low efficiency and non-linear characteristic, it is essential that studies to enlarge the efficiency of PV panels be carried out.

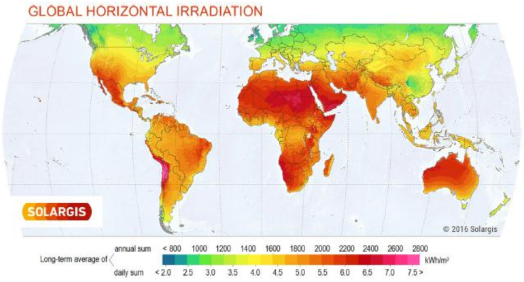

Fig. 1. Global Horizontal Irradiation (GHI) [8].

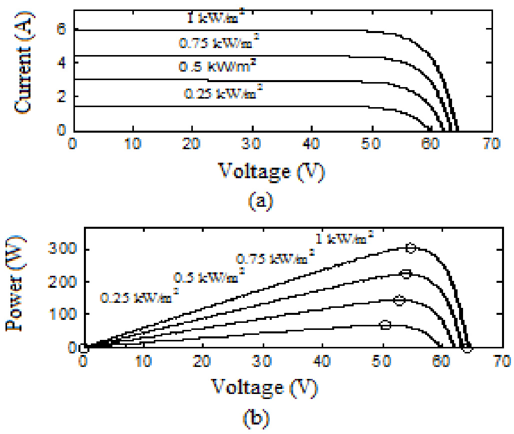

Fig.2. Characteristics of PV panels I-V curve (b) P-V curve

As it is seen from the non-linear characteristic curve of PV panels in Fig.1, depending on the radiation and heat, there comes about a maximum power point (MPP). To reach this MPP, techniques such as maximum power point tracking (MPPT) and incremental conductance (IncCond), Perturb-and-Observe (P&O), Fuzzy logic, Constant Voltage (CV), Constant Current (CC), the particle swarm optimisation (PSO), genetic, proportional-integral (PI) algorithms etc are utilized [11]-[12].

The PV systems are designed as either stand-alone or on-grid [13]-[14]. In the connection of the PV system to the grid, DC-AC converters are used [15] and Voltages produced by PV panels due to radiation and temperature may not be at the level of the power supply of the DC / AC inverters. [16]-[17]. In such cases, by using boost type DC-DC converters, the necessary DC voltage for the inverters is obtained [18]-[19]. However, the increase in the number of converters causes power loss. In this study, in a model PV system connected to the grid and meeting energy consumption need, in the case where the voltage value is not at the needed level, there has been proposed a solution suggestion. In this proposition, the inverter's input DC voltage is constantly measured and when necessary, it is increased with the battery and thus the energy sustainability of PV system is increased.

This paper has been organized as follows: in the material part the PV model, the PV systems independent of the grid and connected to grid, in the methodology part the proposed algorithm of the PV system and experimental set-up, in the results part the results obtained and in the conclusion part a general assessment has been made.

2.Materials

2.1.PV model

The PV models are the kind of energies that convert the radiation and heat they are exposed to directly into electric. The obtained electric is in the DC (direct current) character and the most popular model used to represent the PV module is the current source in parallel with a diode, with a parallel and series resistor [20]. This is illustrated in Fig. 3 and the equation of the circuit in Fig.1 are given equation (1).

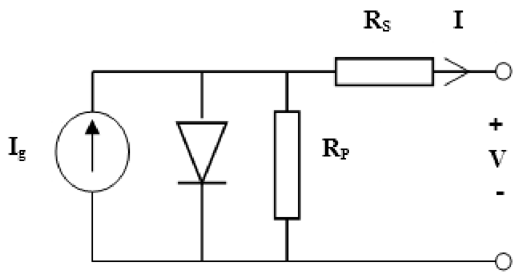

Fig.3. Equivalent circuit diagram for PV model

Solar cells have a current source that are connected with a parallel diode and resistance, to which is connected a serial resistance.

$$I = I_g - I_S\left(e^{\frac{v+iR_S}{a}} - 1\right) - \frac{V+iR_S}{R_P} \qquad (1)$$

In this equation I is the PV current, V is the PV voltage, Rs is the series resistor, Rp is the parallel resistor, Ig is the light-generated current, Is is the diode's saturation current, and a = AkT/q, where A is the diode ideality factor, k is Boltzmann's constant, T is the temperature, and q is the charge of an electron.

2.2.Stand alone (off grid) PV system

Off-grid PV systems are used in such cases as when there is need for electricity but there is no grid, in places that are far away, where the setup of a grid is costly or where there is grid but the power-cuts take place too often. They are mostly used in far-away residential areas where the need for energy is not very high and in industrial applications.

The main equipments used in these systems are solar panel, solar charge control device, battery and where necessary inverters. The direct current (DC) produced by the solar panels is regulated by recharge control device and stored in batteries. While the electrical devices that work with DC are fed either directly by battery or the output of recharge control device, the energy for the alternative current (AC) devices is transferred over an inverter connected to the battery. The consumed electric derives from the produced energy by way of produced energy. Such system store the produced excess energy in batteries. The off-grid system is shown in Fig.4.

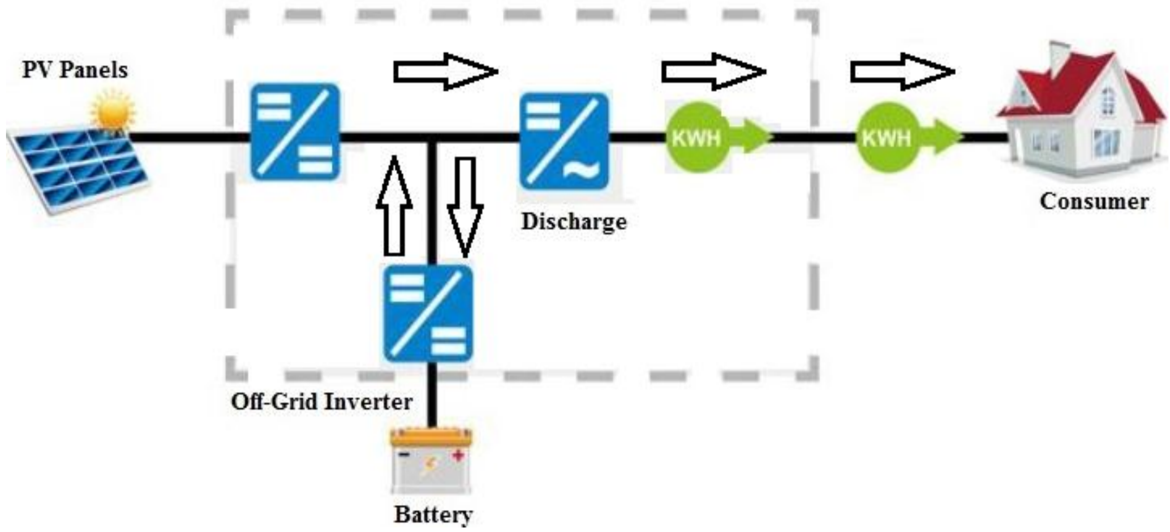

Fig.4. Off grid PV system

2.3.On grid PV system

These are applications working synchronized with grid where the grid is available. As it is working synchronized with the grid, the solar derived energy could be used if there is consumption need in the application field. If there is no consumption need or the energy produced is more than that of consumed then the produced energy is transferred to the grid. The On-Grid PV system is shown in Fig.5.

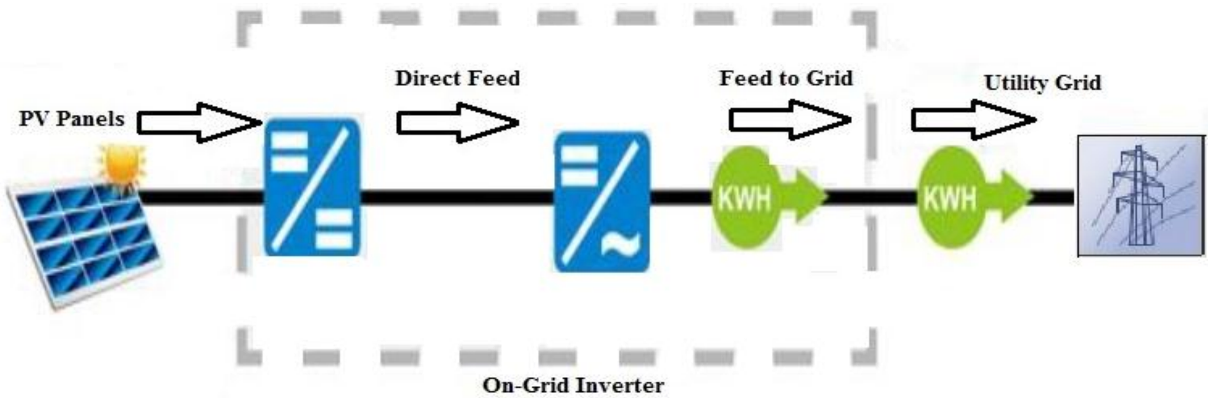

Fig.5. On grid PV system

3.Methods

3.1.The proposed algorithm of the PV system

In the proposed algorithm, the inverter's, which is in on-grid PV systems, full power MPPT minimum voltage range value has been used as a set value. As the range value of the used inverter is 30-60 V level, $V_{minimum\ range}$ = 30 Volt. In this algorithm, firstly the voltage of 3 serial-connected PV panels has been measured with (V_p). Then the measured (V_p) value is compared with $V_{minimum\ range}$ and the Arduino control card's D_2 and D_4 digital output PIN is adjusted to passive or active depending on the case. In case PV panel voltage value is below $V_{minimum\ range}$, D_2 and D_4 digital PINs are activated and the battery is activated. In a reverse case, the PINs are passive. When the battery is activated it is serially connected to the PV panels and the inverter's input voltage value is increased. This way, the voltage needed for the inverter to get connected to the grid is provided. The algorithm of the Proposed PV system is shown in Fig.6.

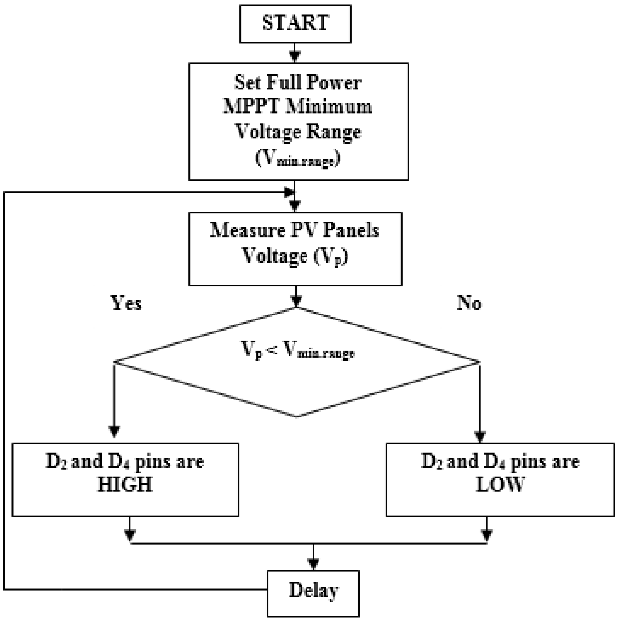

Fig.6. Proposed algorithm

4.Experimental setup

The experimental setup is seen in Fig. 7. It is composed of 3 serially connected 50 W P_{max} of voltage value 17.57 V monocrystalline PV panels, an inverter of 300 W, 12 Volt battery, a dual meter, MPTT charge regulator and DC charge LED lamp.

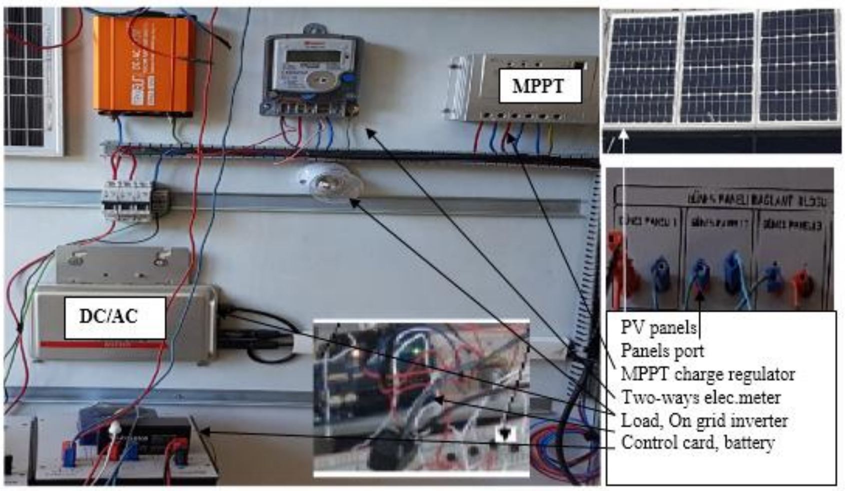

Fig.7. Experimental setup for proposed PV system

The block chart of the application system is seen in Fig. 8. The 300 Watt inverter is connected to the grid. The 10 Watt LED lamp is used as consuming DC charge. The MPPT allows the power transferred to the charge reach the maximum level and recharge the battery. Here below is shown how the proposed system works

.

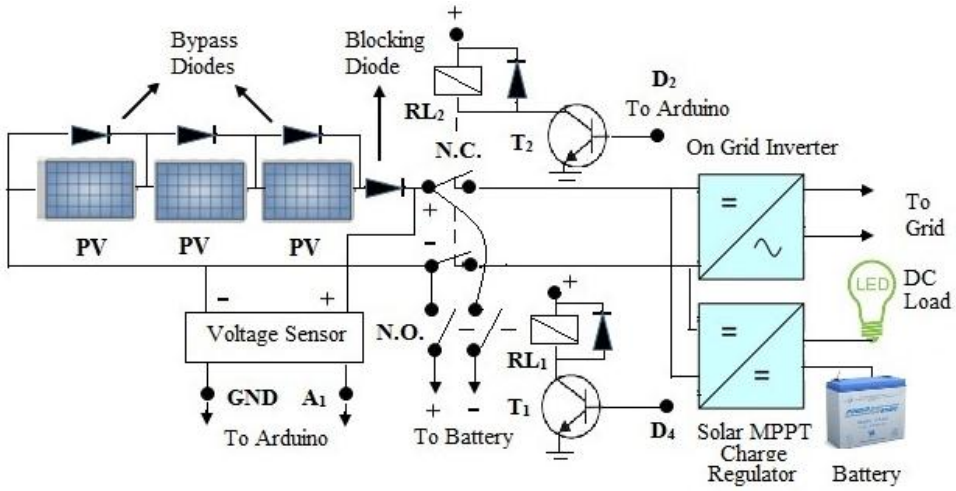

Fig. 8. PV-based smart on grid system block chart

- The obtained voltage value from 3 serially connected PV panels provides the on grid inverter's input DC voltage.
- The voltage of the serial connected PV panels is measured by voltage sensor and the voltage value is given to the Arduino control card's A1 analog input (Fig.9).

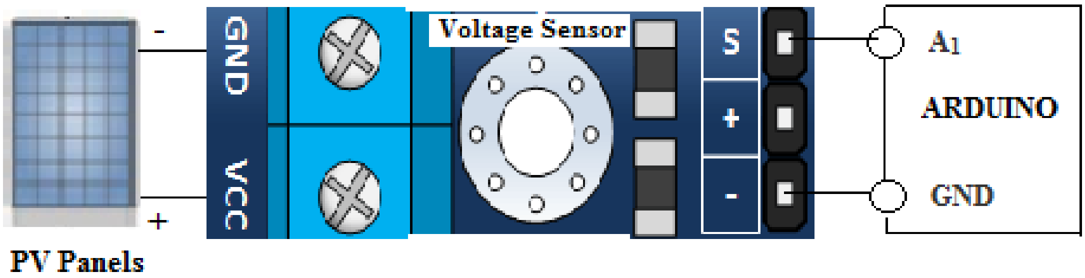

Fig. 9. Connection of voltage sensor between PV panel and Arduino control card

- If the voltage value given to the Arduino control card's A_1 analog input is enough, it will give energy to the inverter grid. If the voltage value is not enough, the D_1 and D_2 PINs of the control card will actively communicate with T_1 and T_2 transistors.
- The T_1 and T_2 transistors control RL_1 and RL_2 relays. The purpose of open and close states of these relays is to connect the battery serially to the PV panels and thus increase the voltage level, as a result of which impede the deactivation of the inverter.

5.Results

With the applied system, when it is cloudy or towards the evening the decreasing PV panel voltage causes the deactivation of the inverter. Thus, when the PV panel power is low, with the support of battery, the low level PV system power will be utilized by adding the inverter to the circuit. If the direct type voltage obtained from the PV panel is at a desired level, the DC/AC converter has been going to give energy to the grid and if it is above the VMVR - VBATTERY difference and below the V_{MVR} value, the D4 pin of the control card will actively switch on the T_1 transistor. In Fig. 9, the case shows the voltage interval of when the transistor is switch on.

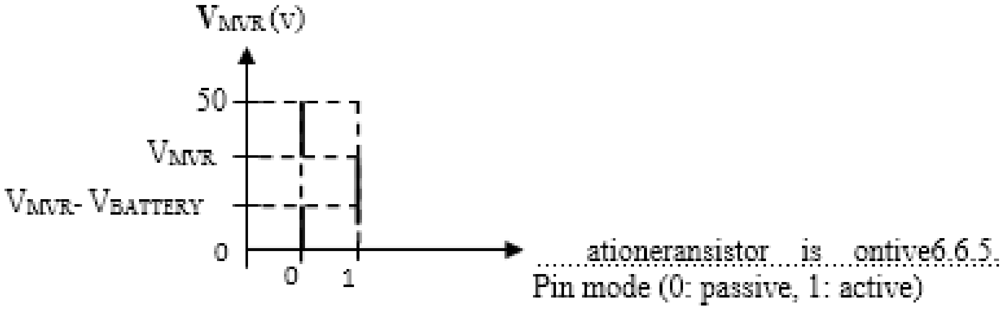

Fig. 10. The voltage region in which the transistor is on and off state

6.Conclusion

While the PV systems occupy an essential place in renewable energy systems, their on-grid uses have been increasing as well. The on-grid inverters that are used to connect PV systems have input voltage range of maximum and minimum. In this study, the voltage information obtained from the PV panels stationed on the roof has been assessed in relation with the proposed algorithm and where the voltage was not enough the battery support was provided and thus the time for the on-grid inverter to connect to the grid has been increased. Hence, the low-efficient PV panels have been benefited in the highest level.

Author Note: This article was presented as oral paper at the SOLARTR2016 Conference.

References

1. Selveraj J., Rahim N.A.,2009. Multilevel Inverter For Grid-Connected PV System Employing Digital PI Controller, *IEEE Transactions on Industrial Electronics*, Vol.56, No.1, pp. 149-158.
2. Özçelik M.A., Yılmaz A.S., 2015. Improving the performance of MPPT in PV systems by modified Perturb-and-Observe algorithm, *Journal of Engineering Research*, Vol.3, No.3, 77-96.
3. Singaravel M.M.R., Dabiel S.A., 2015. MPPT Single DC-DC Converter and Inverter for Grid-Connected Hyrib Wind-Driven PMSG System, *IEEE Transactions on Industrial Electronics*, Vol.62, No.8, 4849-4857.
4. Botelho A., Ligia M.C., et al., 2016. Social sustainability of renewable energy sources in electricity production: An application of the contingent valuation method, *Sustainable Cities and Society*, 26 (2016), pp.429-437.
5. Xiao B., Hang L., Mei J., Rilet C., Tolbert L.M., Ozpineci B., 2015. Modular Cascaded H-Bridge Multilevel PV Inverter With Distributed MPPT for Grid-Connected Applications, *IEEE Transactions on Industry Applications*, Vol.51, No.2, 1722-1731.
6. Carrasco et al., 2006. Power-electronics systems for the grid integration of renewable energy sources: A survey, *IEEE Transactions on Industrial Electronics*, Vol.53, No.4,pp.1002-1016.
7. Shahsavari, A. and Akbari, M., 2018. Potential of solar energy in developing countries for reducing energy-related emissions. *Renewable and Sustainable Energy Reviews*, **90**(2018): pp.275-291.
8. Solar GIS. Global Horizontal Irradiation (GHI); 2016. Available from: <https://solargis.com/maps-and-gis-data/download/world>.
9. Stropnik R., Uro S., 2016. Increasing the efficiency of PV panel with the use of PCM, *Renewable Energy*, 97(2016), pp.671-679.
10. Patel H., Agarwal V., 2008. MATLAB-Based Modeling to Study the Effects of Partial Shading on PV Array Characteristics, *IEEE Transactions on Energy Conversion*, Vol.23, No.1, pp.302-310.
11. Oliveria F.M., Silva S.A.O., Durand F.R., Sampaio L.P., Bacon V.D., Campanhol L.B.G., 2016. Gried-tied photovoltaic system based on PSO MPPT technique with active power line condition, *IET Power Electronic*, Vol.9, Isss.6, pp.1180-1191.
12. Brito M.A.G., Galotto L., Sampaio L.P., Melo G.A., Canesin C.A.,2013. Evaluation of the Main MPPT techniques for Photovoltaic Applications, *IEEE Transactions on Industrial Electronics*, Vol.60, No.3, pp.1156-1167.
13. Vazquez M.J., Marquez J.M.A., Manzano F.S., 2008. A Mehodology for Optimizig Stand-Alone PV-System Size Using Parallel-Connected DC/DC Converters, *IEEE*

Transactions on Industrial Electronics, Vol.55, No.7, pp. 2664-2673.

14. Agarwal R.K., Hussain I., Sing B., 2016. LMF-Based Control Algorithm for Single Stage Three-Phase Grid Integrated Solar PV System, *IEEE Transactions on Sustainable Energy*, Vol.7, No.4, pp. 1379-1387.
15. Hu J., Zhu J., Dorrel D.G., 2015. Model Predictive Control of Grid-Connected Inverters for PV Systems With Flexible Power Regulation and Switching Frequency Reduction, *IEEE Transactions on Industry Applications,*Vol.51, No.1, pp.587-594.
16. Yang Y., Blaabjerg F., 2013. Low-voltage ride-throug capability of a single-stage single-phase photovoltaic system connected to the low-voltage grid, *International Journal Photoenergy*,2013, pp.1-9.
17. Wu T.F., Chang C.H., Lin L.C., et al., 2011. Power loss comparison of single-and two-stage grid-connected photovoltaic systems, *IEEE Transactions on Energy Conversion*, Vol.26, No.2, pp. 707-715.
18. Freitas A.A.A., Tofoli F.L., Junior S., et al., 2015. High-Voltage Gain DC-DC Boost Converter with Coupled Inductırs for Photovoltaic Systems, *IET Power Electronic*, Vol.8, No.10, pp.1185-1892.
19. Walker R.G., Sernia C.P., 2004. Cascaded DC-DC Converter Connection of Photovoltaic Modules, *IEEE Transactions on Power Electronic*, Vol.19, No.4, pp.1130-1139.
20. Bennett T., Zilouchian A., 2012. Messenger R., Photovoltaic Model and Converter Topology Considerations for MPPT Purposes, *Solar Energy*, Vol.86, pp. 2029-2040.