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PHOTOVOLTAIC FARM WITH MAXIMUM POWER POINT TRACKER USING HILL CLIMBING ALGORITHM

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ABSTRACT

The electric power generated by photovoltaic depends on the radiation of sunlight and the temperature generated so that the photovoltaic will have an average maximum energy level during the day. Photovoltaic that is used directly to generate electrical power will not be optimal because solar radiation is affected by the weather. A Maximum Power Point Tracker (MPPT) method on a photovoltaic system is required to harvest the sun's energy optimally. This method works by controlling the duty cycle on the switch converter thereby making the photovoltaic output power to operate at its maximum point. Hill Climbing algorithm is used as a power tracking algorithm embedded into the microcontroller. In this research used 2 photovoltaic 100 WP, Arduino Uno microcontroller and Boost converter to realize photovoltaic farm. Simulation results using a simulator program show that tracking the maximum potential power of 200 Wp photovoltaic can theoretically be implemented. For the potential value of photovoltaic power is 189.79 watts then this algorithm can detect 159.09 watt. In testing implementation using microcontroller found that by using Hill Climbing algorithm can reach 94.9 watt power from potency value of 113.68 watt photovoltaic.

Keywords: photovoltaic, mppt, hill climbing, boost converter, microcontroller.

1. INTRODUCTION

Solar energy is the greatest energy on earth. The existence of a very abundant source of solar energy makes the application of photovoltaic technology (PV) to be an alternative in the generation of electricity. PV technology is the most popular and promising source of renewable energy [1]. This technology is environmentally friendly, durable, maintenance free and not moving / rotating objects [2-5] so as to be potentially future [6].

PV is a tool with semiconductor materials that can convert solar energy into electrical energy. PV cells convert energy in light photons to electrical energy [3-4, 7-8]. But the PV power generation is highly dependent on the weather that greatly affects the efficiency and power output of PV [9-10]. In the application of this technology will be more useful if it produces electrical energy optimally continuously in all weather conditions [11].

When examined from the characteristics of V-I, photovoltaic has nonlinear characteristics and changes to radiation and temperature. In general, there is a peak point called Maximum Power Point (MPP) where at that point photovoltaic works at maximum efficiency. The location of the MPP is unknown, but can be searched. Therefore the Maximum Power Point Tracker (MPPT) algorithm is required to keep the working point of the solar cell to remain at the MPP point [12-14]. Many MPPT methods have been developed. Hill-climbing method is widely applied to MPPT controllers because of its simplicity and easy implementation [15-16].

In this research, simulation and implementation test was done to maintain photovoltaic power in optimum position using MPPT hill climbing algorithm with DC-DC boost converter circuit as its controller. The design is intended for the application of photovoltaic farms with 2 photovoltaic as the basis for optimum alternative power generation prototype analysis

2. MATERIAL AND METHODS

2.1 MPPT system configuration

The MPPT system configuration created in this study is shown in Figure-1.

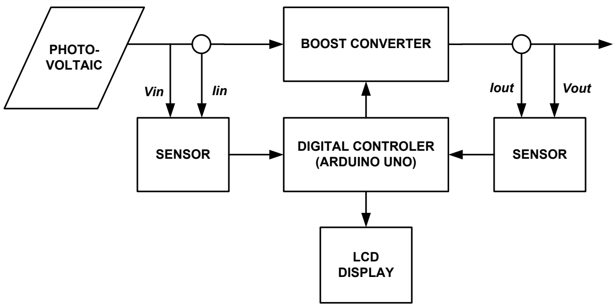

Figure-1. Block diagram of MPPT system configuration.

In this MPPT system consists of two series of systems namely hardware and software systems. The hardware consists of a Boost Converter DC-DC converter circuit, as the main circuit, as well as Arduino Uno microcontroller sensors and circuits. Boost Converter is used to raise the voltage so that the output power generated will be greater. The switching control system of Boost Converter is controlled by the IRFP540 MOSFET, which gets PWM pulses from the microcontroller. Control driver required between Boost Converter with microcontroller to avoid microcontroller damaged due to backflow from main circuit to microcontroller, this circuit is called PWM driver circuit by using TLP250 IC. The software system, hill climbing algorithm aims at searching for peak photovoltaic power values. This software is embedded in the microcontroller. Using the parameters of sensor voltage readings and current sensors, the MPPT hill climbing algorithm produces a manipulated PWM to perform the switching process on the IRFP540 MOSFET.

2.2 Boost converter

The Boost converter circuit consists of inductor (L), diode (D), capacitor (C), and MOSFET switch (M). Inductors and diodes on the boost converter serve as current and voltage sources and to limit the ripple of the output current. Capacitor in the boost converter serves to limit the output voltage ripple. This boost converter circuit is used to raise the input voltage for 2 Photovoltaic to about 48 Volts. The way the circuit works on the incoming voltage conditions to the inductor then causes the rise of current based on time. And when the switch condition is off (M) then the inductor tip (L) is positive, the forward bias diode will charge the voltage on the capacitor and with the voltage across the capacitor greater than the input voltage then in the same time the inductor current will flow on the capacitor and load. When the switch conditions are on again, the voltage and current on the load will only be supplied by the capacitor. The Boost Converter circuit is shown in Figure-2.

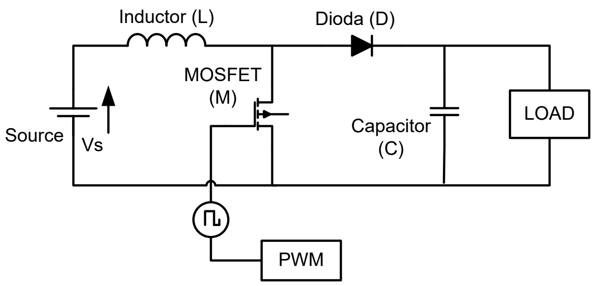

Figure-2. Boost converter circuit.

To calculate the values of each component of the boost converter can be calculated using equations (1) through (5).

Duty Cycle: $$Duty = 1 - \frac{V_{in\_min}}{V_{out}} \quad (1)$$

Output Current: $$R = \frac{V_o^2}{P} \rightarrow I_O = \frac{V_o}{R} \quad (2)$$

Induktor value: $$L = \frac{D \times V_{in}}{\Delta i_L f} \quad (3)$$

Capacitor value: $$C = \frac{D}{R \times \Delta V_0 / V_o \times f} \quad (4)$$

Reference voltage value: $$V_{out}\_reff = \frac{V_{in}}{1-(D/100)} \quad (5)$$

2.3 Pulse width modulation

The PWM circuit is used to provide ignition on the IRFP540 type MOSFET device, using analog PWM is easier to change the frequency and duty cycle values manually

2.4 Voltage sensor

The voltage sensor refers to the principle of using a voltage divider, with a maximum input voltage of 40 volts, and a voltage sensor reading as well as a 5 volt voltage read on a microcontroller ADC. The following is a voltage divider calculation, with the initial parameters determined that the magnitude of Vout is not more than 5 Volts and the maximum Vin is 40 volts, then the value of the two resistors is the fixed resistor R1 determined by 10 KOhm and the magnitude of the variable R2 resistor is searched using equation (6).

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2} \quad (6)$$

2.5 Current sensor

Current sensors are used to measure the current coming out of the photovoltaic, so as to know the current changes. In the current sensor circuit there is a filter capacitor that can make current readings into DC voltage as the output signal is more stable. Current sensor used is current sensor type ACS 712. Sensor used in this research is IC with current rating 20 ampere. This adjusts to the current output from solar panels that can reach 5.8 amperes. IC ACS 712 can be used to censor AC or DC current. The output from the current sensor in the form of DC voltage will be used as read input on the microcontroller ADC.

2.6 Hill climbing algorithm

There are several ways to set the maximum power point. In this study selected hill climbing algorithm as the MPPT control algorithm because the computation is easy and fast and easy to operate. Figure-3 shows the PV power curve as a function of voltage (P-V curve). Begin by measuring the present value of the voltage of the solar cell, V(k) and current, I(k). These two parameters will be combined and will generate power P(k). From these parameters, compared the previous data reading parameters, P(k-1) and V(k-1). The result of this comparison is obtained ΔP and ΔV. Meanwhile the division between ΔP and ΔV is called slope, equation (7).

$$Slope = \frac{\Delta P}{\Delta V} \quad (7)$$

The slope direction is determined by comparison ΔP and ΔV. If the result of the comparison (slope) produces a positive value then the duty cycle is increased

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so that the voltage value increases and if negative then the duty cycle is lowered so that the voltage value is reduced.

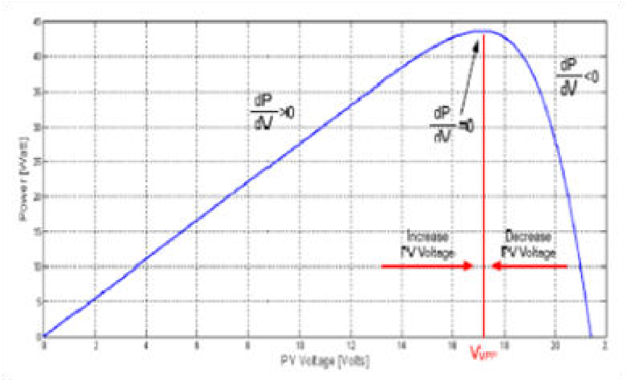

Figure-3. P-V curve for MPP condition [17].

The flow diagram of the hill climbing algorithm is shown in Figure-4. Starting from the reading of the voltage, V and current values, the ADC conversion results in the microcontroller, then the data is processed into P (n) = V (n) x I (n). From the two parameters V and I the input power of P (n) and with V (n) is compared with the previous reading parameter, P (n-1) and V (n-1). The comparison result is obtained ΔP and ΔV. And the result of division ΔP and ΔV is obtained by data, if ΔP / ΔV> 0 then the duty cycle value is D = D (n) + 5, which value D (n) is the previous duty cycle reading plus 5% increase. Whereas if ΔP / ΔV <0 then the duty cycle D = D (n) - 5, which is the duty cycle value minus 5%.

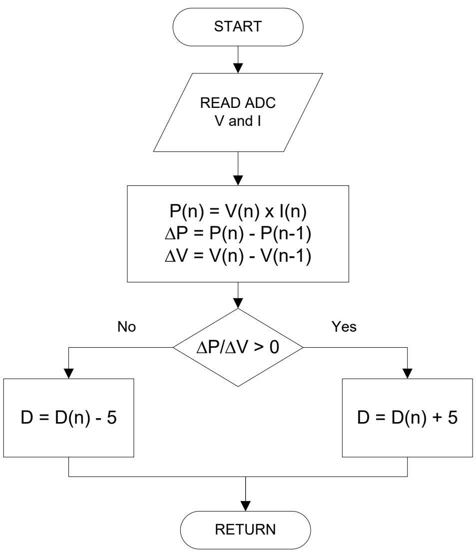

Figure-4. Flowchart of hill climbing algorithm.

2.7 Simulation modeling

Simulation modeling and testing is done using PSIM software, simulation testing includes power testing without hill climbing algorithm and power testing with hill climbing algorithm. The series of tests using photovoltaic adapted to the same parameters as the actual 200Wp photovoltaic parameters are sequenced in series later using a DC voltage source whose amplitude value is 950 because it is adapted to actual weather conditions, then a constant temperature value of 25°C as the input power to the photovoltaic with load resistor of different sizes that is 30Ohm, 50Ohm, 70Ohm, and 90Ohm. Simulation test circuit without MPPT shown in Figure-5.

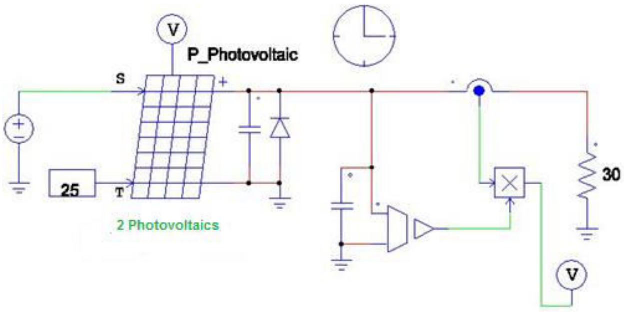

Figure-5. Simulation test circuit without MPPT.

Simulation modeling uses peak peak power search algorithm using Hill Climbing algorithm. The test circuit in this simulator is shown in Figure-6. The parameter values used in the Boost Converter topology are the same as the values of the parameters used in the real hardware whether the inductor value is 290.645uH or the value of the other components. As for the variable of light intensity remains the same as the previous test without using hill climbing algorithm.

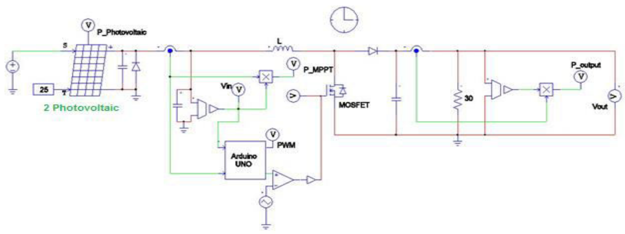

Figure-6. Simulation test circuit with MPPT.

3. RESULTS AND DISCUSSIONS

The first test conducted in this study is testing the characteristics of PV. Then proceed with simulation test using PSIM before testing implementation.

3.1. Testing result of photovoltaic characteristic

Testing of photovoltaic characteristic is needed as basic reference of design of DC-DC converter used in this research. Figure-7 shows a series of characteristic tests of 2 photovoltaic arranged in series. This characteristic data was taken on Monday, July 25, 2017 with cloudy predominantly bright climatic weather parameters with an average temperature of 49°C, the following photovoltaic characteristic parameters:

- Input Voltage : 40 volt
- Maximum Power : 200 Wp
- Input Current : 5,46 ampere
- Switching frequency : 40 kHz
- Temperature : 49° C

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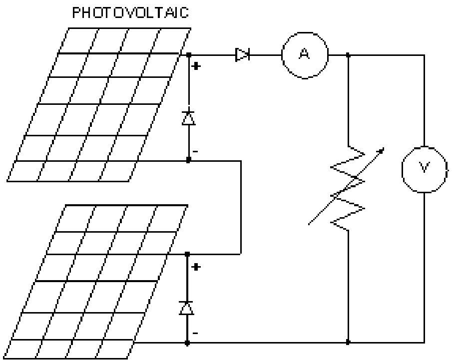
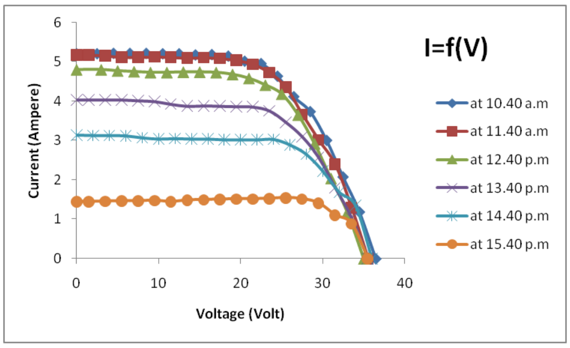
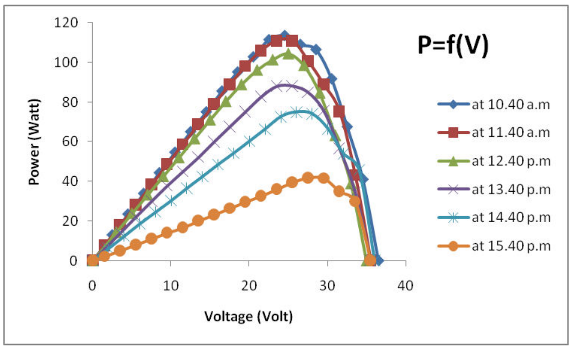


Figure-7. Testing circuit photovoltaic characteristic.

The data obtained from the 200Wp photovoltaic characteristic test are then displayed in graphical form I-V and P-V photovoltaic characteristics shown in Figures 8 (a) and 8 (b). These graphs are needed in the study to determine the photovoltaic characteristics based on changes in time, voltage and current variables and finally on the graph of current characteristics against the potential power generated. From this test obtained the highest power generated from 2 pieces of this photovoltaic of 113.68 watt measured at 10:40 in cloudy conditions.



(a)



(b)

Figure-8. Characteristic (a) I-V and (b) P-V Photovoltaic 200W test result.

3.2 Testing result of simulation

Simulation modeling and testing were performed using PSIM software, simulation testing included a power test without MPPT using the design of 2 PVs without MPPT system shown in Figure-4 and power testing with MPPT using a 2 PV system design with MPPT shown in Figure-5. Figure-9 is shown simulation test curve without MPPT with 30 Ohm load, power generated was 64.07 watt. For load 50 Ohm, 70 Ohm and 90 Ohm, power generated were 39.25 watt, 28,279 watt and 22,097 watt.

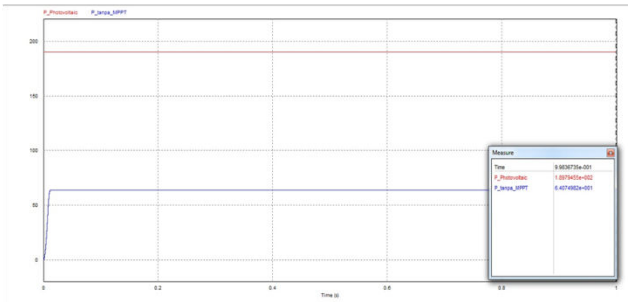


Figure-9. The testing curve without MPPT with 30 Ohm load.

Figure-10 shows the simulation test curve with MPPT for 30 Ohm load, power generated was 153.087 watt. For loads of 50 Ohm, 70 Ohm and 90 Ohm, the power generated were 99,727 watt, 73.26 watt and 57,857 watt.

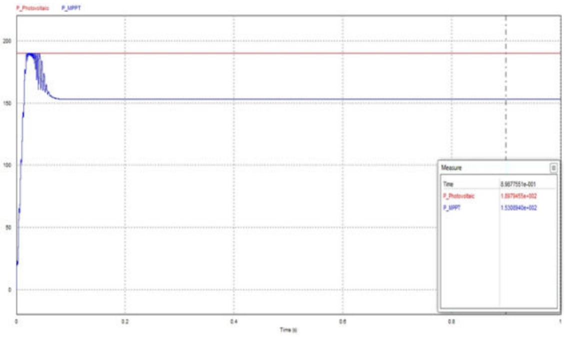


Figure-10. The testing curve with MPPT with 30 Ohm load.

3.3 Testing result of implementation

Testing MPPT system where the direct PV input using exposure to solar radiation accompanied by microcontroller device that has been implanted peak power peak algorithm, that is MPPT using Hill Climbing algorithm. For the load using a rheostat to load can be variable and also resistant to heat considering the power output is large enough. Data retrieval is done by real time, the value taken is Vin, Iin, power, and the amount of PWM issued. The value of these parameters will be displayed via LCD display. The performance test of MPPT system is done by using comparison data. The first test is a PV test that directly loads rheostat, while the second test is to install the MPPT system and boost converter. Each power yield is then compared.

The MPPT system testing device is shown in Figure-10. The test data of PV 200 Wp system with MPPT and without MPPT can be seen in Table-1. From the table it is clear that the measured power difference between the use of peak power search algorithm and without algorithm.

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Table-1. Percentage increase of Power between without MPPT and with MPPT for loads 30, 50, 70 and 90 Ohm.

Load (Ohm)	**Time**	**Pout** (Watt)		**Power up** (%)
		Without MPPT	**With MPPT**	
30	12.30	39,78	52,7	24,52
	13.30	42,245	73,34	42,40
	14.30	30,6	38,76	21,05
50	12.30	26,27	56,43	53,45
	13.30	27,38	90,96	69,90
	14.30	24,48	57,46	57,40
70	12.30	19,08	56,732	66,37
	13.30	19,875	94,24	78,91
	14.30	17,952	71,68	74,96
90	12.30	18,13	67,6	73,18
	13.30	15,876	94,9	83,27
	14.30	14,76	80,94	81,76

From the total measurement data obtained the highest percentage of power increase of 83.27% occurred at 90 Ohm load and time at 13.30 p.m, where the measured power with MPPT and without MPPT is 15.88 watt and 94.9 watt. Figure-11 shows the measured power graph for the 2 conditions at 3 different times and loads 30, 50, 70 and 90 Ohm.

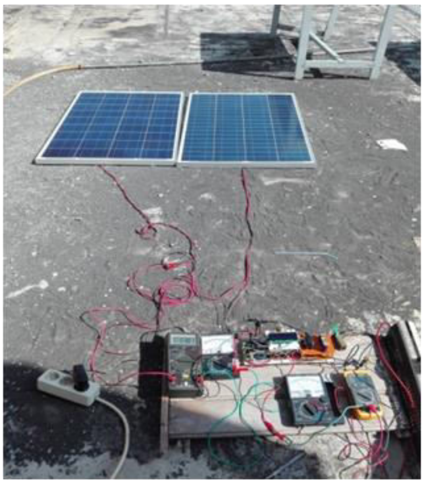
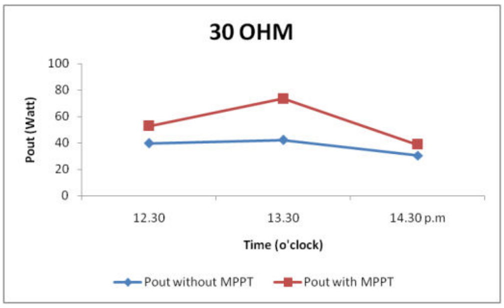
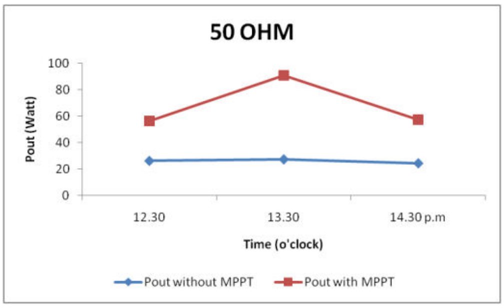


Figure-11. Implementation test.

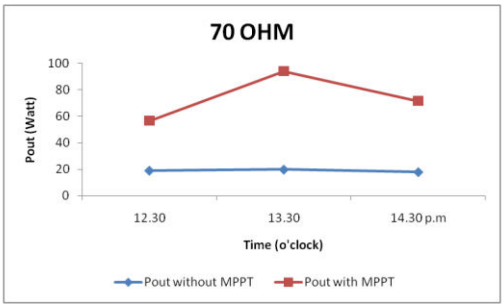
From the comparison of the two systems, it is clear that there is a significant difference between the two. In the previous test, it has been presented in Figure-7, which describes the actual characteristics for PV 200Wp, as shown by the maximum peak power that can reach 113.8 watt. While in testing the system using Hill Climbing algorithm can be analyzed that the measured power when testing showed 94.9 watt value close to the peak power on the characteristics of the PV.



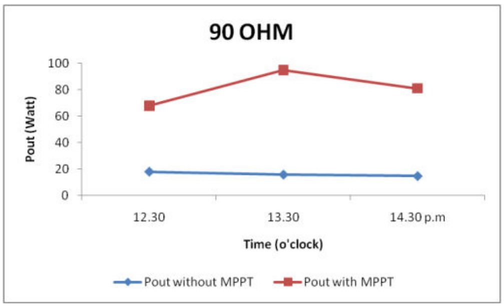
(a)



(b)



(c)



(d)

Figure-12. Comparison of MPPT algorithm.

CONCLUSIONS

Both are reviewed in the simulation and implementation, the method of harvesting solar photovoltaic Maximum Power Point Tracker (MPPT) algorithms Hill Climbing is a method that can be realized because the algorithm can follow the change of power. The system used consists of PV, boost converter and micro controler. The result of the simulation test is capable of reaching 159.09 watt, while the peak potential of photovoltaic 189.79 W. But the implementation test results, the biggest power increase is 94.9 watt, while on testing the photovoltaic characteristics of 200 Wp, peak power can reach 113.68 watt. There is a significant difference between the two values, unlike the results shown in the simulation. This is usually due to the simulation value of each component is very precise in contrast to the actual value of the component that sometimes there is a value of tolerance.

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REFERENCES

[1] Yafaoui A., B. Wu and R. Cheung. 2007. Implementation of maximum power point tracking algorithm for residential photovoltaic systems. Proceedings of the 2nd Canadian Solar Building Conference.

[2] G. Carannante C., Fraddanno M., Pagano L., Piegari. 2009. Experimental Performance of MPPT Algorithm for Photovoltaic Sources Subject to in homogeneous Insolation. IEEE Trans Ind. Electron. 56(11): 4374-4380.

[3] H. Patel, V. Agarwal. 2008. Maximum power point tracking scheme for PV systems operating under partially shaded conditions. IEEE Trans Ind. Electron. 55(4): 1689-1698.

[4] Subudhi B. and Pradhan R. 2013. A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems. IEEE Transactions on Sustainable Energy. 4, 89-98.

[5] Gurung A. 2011. Green Investing 2011. Reducing the Cost of Financing. World Economic Forum USA Inc., USA.

[6] L. F. L. Villa, D. Picault, B. Raison, S. Bacha, A. Labonne. 2012. Maximizing the power output of partially shaded photovoltaic plants through optimization of the interconnections among its modules. IEEE Journal of Photovoltaics. 2(2): 154-163.

[7] P. Lei, Y. Li, J. E. Seem. 2011. Sequential ESC-Based global MPPT control for photovoltaic array with variable shading. IEEE Trans. Sustainable Energy. 2(3).

[8] Wassila Issaadi. 2016. An Improved MPPT Converter Using Current Compensation Method for PV-Applications, International Journal of Renewable Energy Research. 6(3).

[9] Y.-H. Chang and C.-Y. Chang. 2008. A Maximum Power Point Tracking of PV System by Scaling Fuzzy Control. Presented at International Multi Conference of Engineers and Computer Scientists, Hong Kong.

[10] S.Mekhilef. 2008. Performance of grid connected inverter with maximum power point tracker and power factor control. International Journal of Power Electronics. 1: 49-62.

[11] Nedumgatt J.J., S. Jayakrishnan, S. Umashankar, D. Vijayakumar and D. Kothari. 2011. Perturb and observe mppt algorithm for solar pv systems-modeling and simulation. Proceeding of the 2011 Annual IEEE India Conference (INDICON). pp. 1-6.

[12] R. Faranda and S. Leva. 2008. Energy Comparison of MPPT techniques for PV Systems," WSES Transaction on Power Systems. 3: 446-455.

[13] Liu, S. and R.A. Dougal. 2002. Dynamic multiphysics model for solar array. IEEE T. Energy Conver. 17(2): 285-294.

[14] Mohamed Amine Abdourraziq, Mohammed Ouassaid, Member, IEEE, Mohamed Maaroufi. 2016. Single-Sensor Based MPPT for Photovoltaic Systems. International Journal of Renewable Energy Research. 6(2).

[15] Calavia, M., J. Perié, J. Sanz and J. Sallán, 2010. Comparison of mppt strategies for solar modules. Proceeding of the International Conference on Renewable Energies and Power Quality. pp. 22-25.

[16] Mohammad Iman Bahari, 2016. Modeling and Simulation of Hill Climbig MPPT Algorithm for Photo Voltaic Application. International Symposium on Power Electronics, Electrical Drives, Automation and Motion.

[17] Darmawan, Dianggoro. 2011. Design of Maximum Point Tracker (MPPT) For Solar Panels Using Converter with Hill Climbing Methods, the actual component values sometimes have tolerance values. Thesis, ITS Surabaya.