The application of perturb and observe algorithm to optimized of solar cell output

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Abstract — solar cell energy generated varies greatly and is highly dependent on weather conditions. This study implements the algorithm Peturb and observe on a MPPT controller as for solar energy generation. This microcontroller control DC buck converter and is used for charging the battery 12 V, 60 Ah. Method operates with a voltage or current perturbing terminal array and compare the power generated by solar panel output. Required perturbing accordingly to get the true optimization value. Validation of solar panels using the proposed MPPT methods gives better performance which is proven by the power and value of the voltage. Use the perturbation parameter to 0.1, the MPPT is able to optimize the power output of a solar panel 558 W with the 5 ohm load and value irradiation 783 W/m² compared with the conventional method with the irradiation value and the same load of 786 W/m² which generate power output 356 W.

1. Introduction

Recently, the concern for environmental issue has been rising in the world such as global warming by exhausting carbon dioxide (CO2) and breaking of ozone layer by freon gas. On December 1997, during the Kyoto Conference on Climate Change (COP3) it was agreed that by the year 2012 the developed countries would reduce at least 5% of the greenhouse gases compared with year 1990 [1]. Moreover, the global energy shortage and the need for sustainable energy systems enforce the development of power supply structures that are based on renewable resources.

Photovoltaic (PV) system is gaining increased importance as a renewable source due to advantages such as the absence of fuel cost, little maintenance and no noise and wear due to absence of moving parts. But there are still two principal barriers to the use of photovoltaic systems. The high installation cost and the low energy conversion efficiency.

A PV panel is a non-linear power source, that is output current or power depends on the terminal operating voltage and the maximum power generated by the system changes with solar radiation and temperature. To increase the ratio output power/cost of installation it is important that PV panel operates in maximum output power (MPP).

This paper will aboard two principal subjects is the MPPT algorithms using a DC/DC converter and the lead-acid batteries charging process. Thus, this work shows the design and the prototype implementation of a MPPT algorithm for photovoltaic system with the objective to improve energy accumulation. This MPPT algorithm is integrated in one of the main stages of the charging process of lead-acid batteries making an autonomous system that can be used to feed any autonomous application. The P&O MPPT algorithm is used to control the maximum transfer power from a PV panel. This
The algorithm is executed by a microcontroller using the PV voltage and current data to control the duty cycle of a pulse width modulation signal applied to a DC/DC converter. The schematic and design of the DC/DC converter is explained. This MPPT algorithm is used in one of the two main charging stages of a lead-acid battery. Finally, the two main charging stages of a lead-acid battery are presented and experimental results of the performance of the designed P&O MPPT algorithm are presented and compared with the results achieved with the direct connection of the PV panel to the battery.

One of the most frequently used MPPT methods is the perturbation and observation algorithm, although this algorithm has some converging problems with rapidly insolation changes. This problem can be solved using the solution presented in [2]. In this work, PV voltage and current are measured in the middle of the sampling period, making possible to determine if the verified changes are due to perturbation algorithm or shadows that cover the PV panel. Another popular MPPT algorithm is the incremental conductance method (IncCond) [3]. The authors developed the incremental conductance MPPT algorithm avoiding the drawbacks of the P&O MPPT algorithm. It is based on the fact that the derivative of the output power \( P \) with respect to the panel voltage \( V \) is equal to zero at the maximum power point (MPP). The solar panel's P-V characteristics presented in Fig. 2 show further that the derivative is greater than zero to the left of the MPP and less than zero to the right of the MPP. This algorithm shows that enough information is gathered to determine the relative location of the MPP by measuring only the incremental and instantaneous panel conductance’s \( \frac{dI}{dV} \) and \( I/V \), respectively. In this work the Perturb and Observe MPPT algorithm was chosen, due to its simplicity and to its low computational power needs [4]. This work will also show and explain the different charging stages of a lead-acid battery.

2. Solar Array Characteristics

The maximum power point of a solar panel changes in accordance with changes in the solar irradiance and panel temperature. The typical characteristic curves current versus voltage, power versus voltage at different levels of solar irradiation and power versus voltage at different temperatures, are illustrated in figure 1 and figure 2 respectively.

![Figure 1](image-url) **Figure 1.** I-V characteristics of a photovoltaic panel for various values of irradiance \( S \) at a temperature of 25 °C.
The current source region, in which the internal impedance of the panel is high, is at the left side of the current-voltage curve. The MPP of the panel is located at the knee of the current-voltage curve. According to the maximum power transfer theory, the power delivered to the load is maximum when the source internal impedance matches the load impedance.

Thus, the impedance seen from the converter input side (can be adjusted by PWM control signal) needs to match the internal impedance of the panel if the system is required to operate at or near the MPP of the solar array. If the system operates on the voltage source region (namely low impedance region) of panel characteristic curve, the panel terminal voltage will collapse [5].

From Fig. 1 and Fig. 2, it is observed that each curve has a maximum power point (MPP), which is the optimal point for the efficient use of the panel and this point depends of the values of the temperature. The main function of a MPPT is to adjust the panel output voltage to a value which the panel supplies the maximum energy to the load [6].

3. Maximum Power Point Tracking
When a PV module is directly connected to a load, the PV module operating point will be at the intersection of its I-V characteristic and the load line which is I-V relationship of the load [11]. In general this operating point is not at the PV array’s MPP, which can be clearly seen in fig. 3

Thus, in a direct-coupled system, the PV array must usually be oversized to ensure that the load’s power requirements can be supplied. This lead to an overly expensive system. To overcome this problem, a switch-mode power converter, can be used to maintain the PV’s operating point at the MPP. The MPPT does this by controlling the PV array’s voltage or current independently of those of the load. However, the location of the MPP in the I-V characteristic is not known a priori. It must be located, either through model calculation or by search algorithm. The situation is further complicated by the fact that the MPP depends in a nonlinear way of irradiance and temperature [12].
4. Research Method

4.1 Output Characteristics Of Solar Cell
Output power solar cell is a non-linear function against temperature and light intensity [15]. Pictures 1 and 2 show the relationship between temperature against the output power and intensity against the output power of solar cell. Figure 2 illustrates the power output of the solar cells increases with the value of the intensity of light received. For the value of the temperature and different irradiation, each maximum output power will be obtained and is known as the Maximum Power Point (MPP).

![Figure 4. The relationship between temperature against the output power](image1)

![Figure 5. The relationship between intensity against the output power](image2)

4.2 Maximum Power Point Tracker (MPPT)
It is a method to determine the point at which the maximum power generated by the solar panels. Based on research conducted by Priananda and Sulistyowati [7], one of the advantages of the use of the MPPT is quick to satisfy the condition of equilibrium photovoltaics for the conditions required by the load and which can be filled with solar panels. MPPT requires two components supporting the input current to operate. The two components are combined to get the power value P as in equation 1.

\[ P = V \times I \]  

(1)

In conditions of temperature and different irradiation, retrieved the value of the MPP are different. The proper method is required to obtain the value of the maximum power generated by the solar panels.

4.3 Method Perturb and Observe
In his research report on Perturb and Observe method consists of two phases [16]: (1) change to perturb, sending a voltage or a current reference solar cell (2) observe, perform the calculation power caused by perturb him. Benchmarking power before and after the perturb the process done as a reference used to increase or decrease the voltage to the next step and get the value of the MPP.

In the research it does, Francis et al using algorithms and started it by measuring the voltage \( V(k) \) and the current \( I(k) \) to obtain \( P(k) \) [17]. Perturb \( d(V) \) given to observe the value of the output power \( P(k+1) \). The value of \( P(k+1) \) and then compared to its \( P(k) \). If the value of \( P(k+1) \) bigger than \( P(k) \) it can be concluded that perturb niali does is correct. Conversely, if the value of \( P(k+1) \) is smaller than
P (k) then perturb should be done in the opposite direction. Thus the value of the Maximum Power Point (MPP) can be obtained. The steps in the method Perturb and Observe it as illustrated by Figure 3.

4.4 DC-DC Converter
DC-DC converter is an electronic device that changed the voltage DC to DC voltage to a different level and others are usually issued a regulated output. Switch model DC-DC converter operates by storing energy inputs while then take it off in the form of voltage or current in a level is not the same. This converter can be compared to transformers since both have similar characteristics in changing the energy input and makes it different in the level of impedance. This converter is usually found in electronic equipment such as mobile phone or notebook. In this research this converter acting as an electrical load can vary the output. This can cause load variations change the operating point of the solar cells so that it can produce the maximum output value.

![Figure 6](image)

**Figure 6.** Schematic diagram tracking using Peturb and Observe algorithm

4.5 Block Diagram of the System.
System used, as illustrated by Figure 4 which consists of several parts:
(1) Solar panels
(2) Load
(3) The MPPT
(4) Controller
(5) DC-DC converter

![Figure 7](image)

**Figure 7.** System block of diagram

This research consists of three principal processes namely measure voltage and current solar cell, solar panel output optimizing method using Perturb and Observe in the MPPT and mounting burden to do testing of the system.

The proposed system using boost converter that is used to lower the input voltage level. The converter is set by the controller and the resulting output is optimized using the method P&O. Input in the form of current and voltage solar panel and output in the form of duty-cycle buck converter which varied using
switches. Perturb and observe these methods can control the solar cell to produce its maximum output voltage.

4.6 Solar Panel
The solar panel used is Showa Arco Solar (FE) Pty. Ltd whose data is given in table 1.

| Table 1. Solar Panel Specifications |
|-------------------------------------|
| Maximum power (Pmax)                | 100 Watt          |
| Maximum power voltage (Vmp)         | 17.5 Volt         |
| Maximum power current (Imp)         | 5.71 Ampere       |
| Open circuit voltage (Voc)          | 21 Volt           |
| Short circuit current (Isc)         | 6.4 Ampere        |

4.7 Voltage Sensor
Solar panel voltage sensors are voltage dividers that use resistors 100 Kohm and 20 KOhm. sensor output has 0 Volt for input 0 Volt and 10 Volt for input 60 Volt.

4.8 Current Sensor
Current sensors used are manufactured by ACS712 -20A Allegro micro system.

4.9 Buck Converter
Buck converter component used for 12 V 60 Ah batteries as in table 2.

| Table 2. Buck Converter Component |
|-----------------------------------|
| Mosfet Driver                    | IRFP 460          |
| Switching frequency              | 20 KHz            |
| Inductor                         | 33 mikro Hendry   |
| Capacitor                        | 470 mikro Farad   |

4.10 Implementation of MPPT
The MPPT is implemented into the system, as illustrated by figure 8.

4.11 Implementation of the Algorithm Perturbe and Observe
Implementation Perturbe and Observe performed with voltage and current measurement is done by the sensor and put in solar cells. Both of these data are used as input mikrokontroller. ADC mikrokontroller using that data to the proposed method. For the first iteration the value 0 is given as the
initial value. Then Perturb and Observe applied and performed calculations and comparisons with previous power. Settings done through the duty cycle. Using the new power voltage value is then measured, and compared the iteration starts again. This algorithm as described figure 9.

![Figure 9. Perturb and Observe algorithm](image)

This algorithm begins by measuring the voltage rating current from the solar panel so that its value will be obtained. The value of the current measurement of the power compared to the previous power measurements. If the difference between the two measurements is $= 0$ then the value of the voltage, current and power will be used as the value of the latest. But if the value of the difference between its $\neq 0$ then it will given the addition and subtraction of voltage in accordance with the specified reference voltage. From this voltage value obtained perturb power latest.

### 4.12 System Testing

The performance is done using solar panel 100 watt peak integrated with battery, load is connected to the terminal block MPPT. Weights used vary. Benchmarking was done between the output of conventional system with MPPT system uses. Irradiasi measurement of the Sun using a pyranometer. The circuit as shown in figure 10.

![Figure 10. Circuit of MPPT](image)
5. Experimental Result
The testing was carried out in the energy conversion laboratory of the electrical engineering department. Performance evaluation was carried out using a 100 Watt peak solar panel which was integrated with batteries, a load connected to the MPPT terminal. The load used is varied. Comparisons are made between conventional system output and systems that use MPPT.

5.1. Voltage Sensor
The test is done by varying the input voltage to see the performance of the voltage sensor, data obtained as in the table 3.

| No | V_multimeter | V_sensor | Error (%) |
|----|--------------|----------|-----------|
| 1  | 40.5         | 40.4     | 0.1       |
| 2  | 41.4         | 41.4     | 0.0       |
| 3  | 42.2         | 42.0     | 0.2       |
| 4  | 43.8         | 43.5     | 0.3       |
| 5  | 44.7         | 44.5     | 0.2       |
| 6  | 45.2         | 45.2     | 0.0       |
| 7  | 46.2         | 46.0     | 0.2       |
| 8  | 47.3         | 47.0     | 0.3       |
| 9  | 49.4         | 48.7     | 0.7       |
| 10 | 51.6         | 50.4     | 1.2       |

Average 0.32

5.2. Current Sensor
The sensor calibration process is carried out by providing various data and comparing the data read by the LCD with a multimeter, the data obtained as in the table 4.

| No | I_multimeter | I_sensor | Error (%) |
|----|--------------|----------|-----------|
| 1  | 6.8          | 6.3      | 0.5       |
| 2  | 6.9          | 6.6      | 0.3       |
| 3  | 7.8          | 7.3      | 0.5       |
| 4  | 8.7          | 8.3      | 0.4       |
| 5  | 8.9          | 8.9      | 0.0       |
| 6  | 9.7          | 9.2      | 0.5       |
| 7  | 9.8          | 9.6      | 0.2       |
| 8  | 10.2         | 10.0     | 0.2       |
| 9  | 10.7         | 10.3     | 0.4       |
| 10 | 11.0         | 11.0     | 0.0       |

Average 0.3

5.3. Battery Voltage Sensor
Storage media testing as in the table 1 the data collection of battery testing was carried out 10 times.

| No | V_multimeter | Sensor voltage | Error (%) |
|----|--------------|----------------|-----------|
| 1  | 6.8          | 6.7            | 0.1       |
| 2  | 7.1          | 7.0            | 0.1       |
| 3  | 7.9          | 7.9            | 0.0       |
| 4  | 8.6          | 8.5            | 0.1       |
| 5  | 9.7          | 9.4            | 0.3       |
| 6  | 10.6         | 10.2           | 0.4       |
| 7  | 11.5         | 11.3           | 0.2       |
Buck converter is used to reduce the input voltage level and provide a stable output. Buck converter test is done by giving a fixed value of V and the results are observed with a variation of the given duty cycle.

| No | V\text{in} | D | V\text{count} | V\text{out, multi} | Error |
|----|------------|---|---------------|---------------------|-------|
| 1  | 10         | 44.35 | 44.30 | 0.05 |
| 2  | 20         | 45.42 | 45.34 | 0.08 |
| 3  | 30         | 46.32 | 46.22 | 0.10 |
| 4  | 40         | 47.21 | 47.10 | 0.11 |
| 5  | 50         | 48.32 | 48.32 | 0.00 |
| 6  | 60         | 49.67 | 49.13 | 0.54 |
| 7  | 70         | 50.11 | 49.90 | 0.21 |
| 8  | 80         | 51.53 | 51.10 | 0.43 |
| 9  | 90         | 52.78 | 52.23 | 0.55 |
| 10 | 95         | 55.78 | 55.12 | 0.66 |
|    | Average    |       |       | 0.55 |

5.5. System Testing
Table 7 shows data retrieval performed on conventional systems and systems connected to MPPT. The data shows the system that is connected by giving greater results. The system is given a load of 5 Ohm-50 Ohm at various irradiation conditions. For the power produced by the image 11 shows a comparison between conventional systems and systems connected to MPPT. The image shows that the power produced is always higher when compared to conventional systems.

From the given load variations to the conventional system when the load power values are given 10 ohm on 353 W to load 10 ohm power increase in the value of 554 W. This case refers to the value of the irradiance sun is received which is also experiencing increased power value. Next trend has decreased in accordance with the given load large for a system with mppt power value has stabilized trend despite the burden of a given variable. It is obtained from the achievement of the maximum power point of a solar panel on every variation of irradiation received.

| No | R | Irradiance | Non MPPT Pout | Irradiance | MPPT Pout |
|----|---|------------|---------------|------------|-----------|
| 1  | 5 | 786        | 356           | 783        | 558       |
| 2  | 10| 755        | 353           | 758        | 554       |
| 3  | 15| 743        | 342           | 744        | 542       |
| 4  | 20| 725        | 330           | 735        | 530       |
| 5  | 25| 710        | 321           | 744        | 521       |
| 6  | 30| 698        | 310           | 688        | 510       |
| 7  | 35| 685        | 318           | 689        | 518       |
| 8  | 40| 668        | 295           | 678        | 495       |
| 9  | 45| 665        | 294           | 657        | 494       |
| 10 | 50| 652        | 278           | 650        | 478       |

6. Conclusion
Conventional methods of producing power W 356 with 786 irradiation W/m² and 5 ohm load. with the
same load system MPPT algorithm Peturb and Observe the output power of 558 Watt with irradiation 783 W/m². The value of the variable irradiation system with MPPT using the proposed method can provide a higher output power compared to the conventional system.

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