AN IMPROVED CONTROLLER BASED ON MPPT CONTROL STRATEGY FOR PHOTOVOLTAIC SYSTEMS

SANUSI Y.K1 & ABIODUN AYODELE O. JOSHUA2

Pure and Applied Physics Department, Ladoke Akintola University of Technology Ogbomoso, Nigeria

ABSTRACT

Improvement in the conversion of solar energy into electrical energy and also the cost reduction has helped increase its growth. Maximum Power Point Tracking plays a vital role in photovoltaic (PV) system because they increase the efficiency of the solar photovoltaic system by increasing the power output. In this paper, two different controllers which are the Conventional (CVN) and the modified Maximum Power Point Tracker (MPPT) were considered. Different MPPT techniques were also considered and the best among the techniques was discovered. A modified algorithm was then developed using the known and efficient algorithms reported such as the P&O, OV and SC. The two controllers were constructed and their performance was evaluated by analyzing the electrical parameters gotten from them in various seasons. The modified algorithm which can be referred to as the modified P&O was compared with the conventional algorithm and a MATLAB program was used to implement all the algorithms. It was then deduced from the results of the performance of the two algorithms that the efficiency of modified MPPT is 45% more than that of conventional system.

KEYWORDS: Maximum Power Point Tracking (MPPT), Photovoltaic (PV), Constant Voltage (CV), Open Voltage (OV), Short Circuit Current (SC), Performance,

INTRODUCTION

Solar energy is one of the most important renewable energy sources, it is very clean, inexhaustible and free. Among several solar energy applications is photovoltaic system. Photovoltaic system is used in solar water pumping, solar battery charging, hybrid vehicles, and other photovoltaic solar devices.

The performance of a photovoltaic (PV) power system depends on the operating conditions as well as the solar cell and array design quality [1]. The output voltage, current and power of a PV array vary as functions of solar irradiation level, temperature, and load current. Therefore, the effects of solar irradiation, temperature, and load current must be considered in the design of PV arrays so that any change in the temperature and solar radiation should not adversely affect the photovoltaic output power to the load which is either a power company utility grid or any stand-alone electrical type load. To overcome the undesired effects of the variable temperature and solar irradiation on the output power of PV systems, different control systems need to be applied. These control systems may be either controlling the sun input to the PV array or by controlling the power output from the PV array. The two systems may include electric or thermal energy storage systems or auxiliary power sources which supply electricity during the nights or cloudy days. Sun input to the PV systems is kept as high as possible either by rearranging the solar cell configurations of PV arrays with respect to changes in weather conditions [3,7,8] or by designing and controlling the position of sun tracking solar collectors [7,9,10]. There are many different approaches
to maximizing the power from a PV system, these range from using simple voltage relationships to more complex multiple sample based analysis. Depending on the end application and the dynamics of the irradiance, the power conversion engineer needs to evaluate the various options.

The PV system is characterized with a non-linear current-voltage varying with solar radiation received on the earth surface and the ambient temperature which affects the output power given by the system. Hence, maximum power point tracking techniques are introduced to boost the PV system’s operation point by monitoring the MPP and trying to ensure the array operates at its MPP at all times[11].

The power delivered by a PV system of one or more photovoltaic cells is dependent on the irradiance, temperature, and the current drawn from the cells. Maximum Power Point Tracking (MPPT) is used to obtain the maximum power from these systems[12]. Such applications as putting power on the grid, charging batteries, or powering an electric motor benefit from MPPT. In such applications, the power require by the load may be higher than the power generate by the PV system. In this case, a power conversion system is used to maximize the power from the PV system[13].

However, in this present work, development of modified maximum power point tracking technique was done by combination and modification of existing techniques. The performance evaluation of the new technique was carried out by writing a program using Matlab to implement the algorithms and simulate the readings and compared it with the convectional controller photovoltaic system[14].

There are different techniques used to track the maximum power point. Few of the most popular techniques considered are[16]:

- Constant Voltage method
- Short-Current Pulse method
- Open Voltage method
- Perturb and Observe method

**Constant Voltage Method**

The constant voltage method is one of the very simple MPPT control technique. The operating point of the PV system is held near to the MPP by adjusting the voltage of PV module and matching it to a particular fixed reference voltage equal to the MPP voltage of the characteristic PV system. The constant voltage technique considers that both the solar radiation and temperature variations on the PV module are not so important factors on the MPP voltage and that the fixed reference voltage is almost equal to the real MPP voltage. Thus, the operating point is not exactly at the MPP and locality data needs to be obtained for different geographical locations. The technique requires PV module voltage measurement in order to set up the duty-cycle of the DC\DC boost converter.
Short-Current Pulse Method

The short-circuit pulse technique operates the MPP by providing a reference current to the power converter controller. The best operating current for maximum power output is directly proportional to short-circuit current under different atmospheric conditions. The technique requires the measurement of the short-circuit current. To achieve this measurement, it is very important to adopt a static switch in parallel with the PV module in order to establish the short-circuit condition. Also, the method requires the measurement of the PV module current in order to set up the duty-cycle of the DC/DC boost converter.

Open Voltage Method

The basic fundamental of open voltage technique is on the observation that the maximum power point voltage is usually close to a fixed percentage of the open-circuit voltage. Solar radiation, temperature and generation spread vary the position of the MPP within a 2% tolerance band [18]. The open voltage method always applies 76% of open voltage as reference value voltage for which the maximum power output can be achieved [18]. The technique needs measurements of the output voltage when the current is opened. The method also requires to adopt a static switch in to the PV module. Moreover, the method requires the measurement of the PV module voltage by the regulator.
Perturb and Observe Method

Perturb and observe method work on intermittent perturbing the module terminal voltage and carry out comparison between the PV power output and that of the previous perturbation cycle. However, if the PV module voltage varies and the power increases, the control system adjust the PV modules operating point in the same way, but if the power decreases, the operating point will be moving in the opposite direction. The algorithm of this method continues in the same pattern for the next perturbation cycle.

METHODOLOGY

There are several things considered in the development of this project. Methodology (process includes the method, technique, and the tools/equipment’s) is a process that has to be followed when analyzing data and designing a project.

Solar Panels

Two similar solar panels were used with specifications below in table 1.
Table 1: Electrical Characteristics of PV Panel

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{MPP}</td>
<td>Maximum Power</td>
<td>130W</td>
</tr>
<tr>
<td>V_{MPP}</td>
<td>Voltage at P_{MPP}</td>
<td>17.60V</td>
</tr>
<tr>
<td>I_{MPP}</td>
<td>Current at P_{MPP}</td>
<td>7.39A</td>
</tr>
<tr>
<td>I_{SC}</td>
<td>Short-Circuit Current</td>
<td>8.13A</td>
</tr>
<tr>
<td>V_{OV}</td>
<td>Open-Circuit Voltage</td>
<td>21.80V</td>
</tr>
</tbody>
</table>

Multi-Meters

Two multi-meters with same resistance were used to measure the current and the voltage of the experimental set-up. This is to avoid variations due to difference in resistance of the instrument. (Mastesch MY64)

Batteries

Two blue gate batteries were used to store charges from each setup, each of 100AH.

Controller

The controller: Two controllers were constructed, detail of construction in [24] – the Maximum Power Point Tracker (modified one) and the Conventional controller which have a current rating of 10A each.

Conventional MPPT Techniques

Classification form of MPPT algorithms may be according to the used control techniques. In literature, many control techniques are developed for this purpose[20]. In the convectional MPPT techniques, P-V characteristic of PV module is used. The power generated by PV module change with respect to the voltage. The main advantages of the algorithm are simple structure and ease of implementation, with both stand-alone and grid-connected systems, MPP tracking can be done with very high efficiency [21, 22, 23,]. But it has limitations that reduce efficiency of MPPT

Modified MPPT Algorithm

After conducting a comprehensive study and analysis of the algorithms considered above, the best three algorithms were combined and a new algorithm was developed. Since the P&O algorithms operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle, it was used as the base algorithm accepting the output of the voltage from the Open Voltage algorithm and the current from the Short-Current algorithm, then periodically perturbs the voltage from the Open Voltage and compares the PV output power with that of the previous perturbation cycle.
Figure 5: Flow Chart of the Modified Algorithm Measurement and Readings

Experimental Set-up

Figure 6 shown the experimental set-up for the both real experiment, MPPT (modified Controller) and control experiment, CVN (conventional controller)

Measurement of Electrical Parameters

The performance of two different MPPT techniques (the convectional and the modified technique) were studied concurrently measuring and recording the following electrical parameters; output current, output voltage and power out of the systems.

Performance Verification and Comparison

The Performance of the two controllers were evaluated from the recorded parameters and compared.
RESULTS AND DISCUSSIONS

The variation of mean values of voltage, current and power for the two controllers considered (modified MPPT and CNV) are displayed graphically in the figures 7: 11. Figure 7: 8 shows the comparison of average monthly variation of maximum power and maximum current for the modified MPPT and CNV systems. While figure 9 – 11 displayed hourly variation of current, voltage and power output for the both modified MPPT and CNV systems.

Generally, it is deduced from the figures 7: 11 that modified MPPT has a better efficiency than the conventional controller as such at every point in time regardless of the magnitude of solar radiation reaching the Solar panels, the system with the MPPT always had a higher output in term of value of current, voltage and power compared to CNV. In the figure 10, the variation of voltage has a seemingly similar curve because the voltage on the battery keeps increasing as it gets more power. However, for the variation of current, there is a distinct difference with the increase in number of hour of the day. This was attributed to the fact that the variation in output of the current of photovoltaic system is a function of the variation in solar radiation of the day. All the figures have similar peak value at the same time range from 12.00pm to 2.00pm, that is for the both systems, the maximum output power was around 1.00pm when the sun is at its zenith. Also, the higher value in magnitude of modified MPPT voltage compared to that of CNV was due to the fact that, though the battery was drained to the same voltage, as soon as they were to be charged, yet, there was a difference even at their first readings with the modified MPPT having a higher charging rate. It is also important to note that the MPPT charged the battery fully while the Conventional controller wasn’t able to achieve that. In some cases where there was also a high fluctuation in solar radiation, the modified MPPT was able to cater for it and still delivered remarkable output.

![Figure 7: Comparison of Variation of Maximum Current with Number of the Months](image1)

![Figure 8: Comparison of Variation of Maximum Power with Number of the Months](image2)
CONCLUSIONS

MPPT algorithms employed in photovoltaic solar systems are one of the most vital factors that determine electrical efficiency of the system. Apart from cost optimization in using MPPT system by the designer, it is also important to take in to consideration which algorithm will be used in application. In this study, the two different MPPT were designed and constructed. The performance of the two were tested and compared in the different time of the day and different months of the year.
It was discovered that at every point in time the modified MPPT delivers about twice the power of the conventional and after simulation with Matlab it was also discovered that for the area of study the best algorithm to be employed is the perturb and observe method. The simulation was first run with readings from the conventional controller and it was observed that the power obtained was averagely 58 Watts. It must be noted that the PV panel generated around 130 Watts power. Therefore, the conversion efficiency came out to be very low.

On the other hand, the simulation was then run with readings from the modified MPPT and it was observed that the power obtained was averagely 97 Watts. Under the same irradiation conditions, the PV panel continued to generate around 90 Watts power, thus increasing the conversion efficiency of the photovoltaic system as a whole. The loss of power from the available 130 Watts generated by the PV panel can be explained by switching losses in the switching circuit and the inductive and capacitive losses in the MPPT circuit.

**RECOMMENDATIONS**

For further study it would be recommended that other MPPT techniques be considered and compared for better understanding of the area of study.

**REFERENCES**


