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Research Article

Implementation Of Modified P&O MPPT In Off-Grid Rooftop Solar Power Systems

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Abstract: PT Hydrateh Smart Indonesia is a company that has implemented rooftop solar PV technology to meet the needs of electric power in the commercial office sector on a small scale. The use of rooftop solar PV is carried out to reduce the load from PLN and to find out how much profit in terms of power efficiency has been generated in the use of rooftop solar PV. As with other renewable energy technologies, the challenge faced by rooftop solar power plants is the fluctuation of the sun, in this case its irradiation, which has an important role in the process of extracting optimal output power. Rapid changes in irradiation affect the utilization of solar energy into electrical energy. This research designs an optimal rooftop solar power plant from the PT Hydratech Smart Indonesia building as a representative of the use of rooftop solar power plants with a capacity of 3600 W equipped with maximum power point tracking (MPPT) to increase the output power value. Of the several MPPT algorithms that have been used, the perturb and observe (P&O) algorithm is the most popular due to its easy implementation and economical price. However, the drawback of this algorithm is the efficiency of its performance which is still fairly low so it is necessary to modify the step size value. The results showed that using the conventional P&O algorithm, MPPT was able to achieve an efficiency of 81.19% and the modified P&O algorithm of 89.06%.

Keywords: PV rooftop, Maximum Power Point Tracking, Perturb and Observe, Step Size.

1. Introduction

The utilization of solar cell technology (photovoltaic or PV) and its application for solar PV rooftops has been implemented by PT. Hydratech Smart Indonesia to meet electricity needs in the commercial office sector. PT. Hydratech Smart Indonesia is a business entity engaged in the smart home system sector with a building area of 23 x 7 meters and a height of 20 meters, currently using electricity from PLN with a capacity of 3500 VA. All electronic devices installed utilize a smart system to facilitate work within PT. Hydratech Smart Indonesia and serve as a portfolio for small-scale commercial rooftop solar PV installations[1].

The rooftop solar PV system (PLTS) generally has low efficiency due to the variability of power generated by the PV panels. This is caused by the dependence on solar radiation, which heavily relies on weather conditions. These conditions are intermittent and unpredictable, making accurate measurement parameters difficult to obtain [2]. The power output of the rooftop solar PV system depends significantly on sunlight.

Several methods can improve the power extraction process. According to previous research, to optimize the power output from PV systems, rooftop solar PV systems need to be equipped with Maximum Power Point Tracking (MPPT). MPPT technology is a method aimed at optimizing system performance by tracking the Maximum Power Point (MPP) under varying sunlight conditions [3], [4].

The main focus of this study is to modify the duty cycle variable of MPPT in the Perturb and Observe (P&O) algorithm, designed through Power Simulator (PSIM) simulation, to address the limitations of the conventional P&O algorithm applied to rooftop solar PV systems. In the conventional P&O algorithm, the disturbance value given to the duty cycle remains constant, whereas in the modified P&O algorithm, the disturbance value changes due to a multiplier factor greater than 0 and less than 1. This study involves modeling a rooftop solar PV system using a modified P&O MPPT algorithm tailored to the load requirements of PT. Hydratech Smart Indonesia.

2. Materials and methods

The data collection methods in this research are as follows:

- **Literature Review**
  A literature review was conducted to gather references related to the design of rooftop solar PV systems, MPPT, P&O, and DC-DC converters. Additionally, data on solar irradiation characteristics and other related parameters were collected as a basis for designing a system to convert solar irradiation into electrical energy.
- **Data Collection**
  Data collection was carried out through direct observation at PT. Hydratech Smart Indonesia. The required data included electricity usage load data obtained from the load usage reports for January–December 2022 and the type of PV used.
- **Modeling**
  The PV specifications data obtained from PT. Hydratech were used to create a rooftop solar PV system model based on solar irradiation variations. At this stage, the MPPT was also designed based on solar irradiation and temperature characteristics as system inputs to maximize the power extraction process.
- **Simulation Result Analysis**
  The modeled system was tested using solar irradiation data, and observations were made regarding its process. Subsequently, an analysis of the entire system was conducted, including the impact of solar irradiation on system output, efficiency, and system performance under dynamic conditions, followed by drawing conclusions.

The overall PV system block diagram is shown in Figure 1. The block diagram consists of a PV module, MPPT, boost converter, and load. This study focuses on the MPPT control circuit, specifically the modification of the P&O algorithm to determine the effect of step size on the output power efficiency of the PV. The PV module functions to convert solar energy into electrical energy. To maximize the system's output power, the P&O algorithm is used to improve tracking accuracy by modifying the step size. This modeling utilizes Power Simulator (PSIM) to validate the proposed circuit.

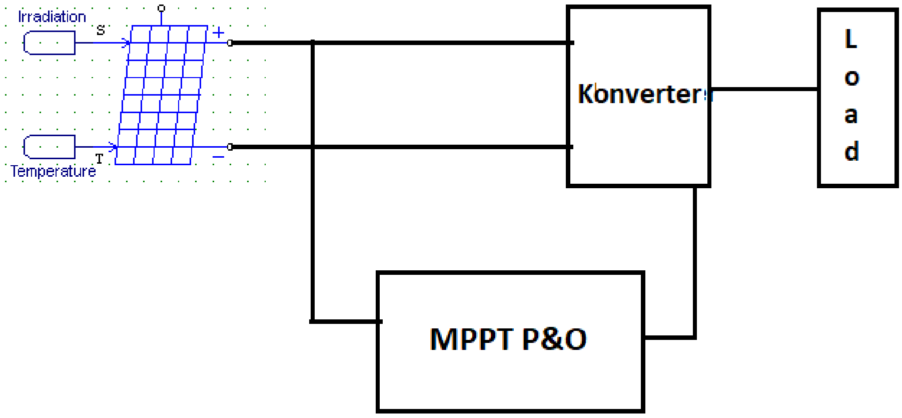

Figure 1. Proposed PV System

The PV module used in this simulation is a Solar Module. The PV module operates under Standard Test Conditions (STC), which is the industry standard for testing PV module performance by specifying a cell surface temperature of 25°C and radiation of 1000 W/m². It utilizes the I-V and P-V characteristic displays for one module @ 25°C and specified irradiances. The module is adjusted to match the original PV module used at PT. Hydratech based on the specifications provided in the datasheet, as shown in Table 2.

Table 1. *Datasheet* PV

Modul type	**Monocristaline Tier 1**
Rate Max Power (Pmax)	450 Wp
Current at Pmax (Imp)	9,50 A
Voltage at Pmax (Vmp)	47,87 V
Short Circuit Current (Isc)	9,73 A
Open Circuit Voltage (Voc)	58,57 V
Dimension	1956*1310*45
Number of cells	96
Max. System Voltage	1000V
Temperature Range	-45^0 – 85^0 C

Table 2. *Datasheet Standard Test Condition (STC)* PV

All values are measured under STC	
Air Mass	1.5
Temperature cell	25^{0}C
Irradiance	1000W/m^2

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After inputting parameters based on the actual specifications of the PV module, module testing can be performed with the input parameters being temperature (T) and light intensity (Ir). Validation and estimation testing were carried out by providing the existing parameters, including temperature, light intensity, and load. The desired results were obtained after the testing was conducted.

Based on the above parameters, a rooftop solar PV system model was created using PSIM under solar irradiation conditions of 1000 W/m² and a temperature of 25°C. The simulation results yielded a maximum PV power of 3614.63 W, which aligns with the capacity of the installed PV module. The DC output voltage from the rectifier then served as the basis for modeling the boost converter.

1. Conventional P&O Algorithm

After modeling the PV system with a boost converter using the conventional P&O algorithm with a fixed step size, the process is illustrated in Figure 3. Initially, the system reads the voltage (VPV) and current (IPV) values from the PV module and calculates the product of current and voltage to determine the PV output power. The product result is used as a basis for evaluation to determine the duty cycle value to maximize the PV output power.

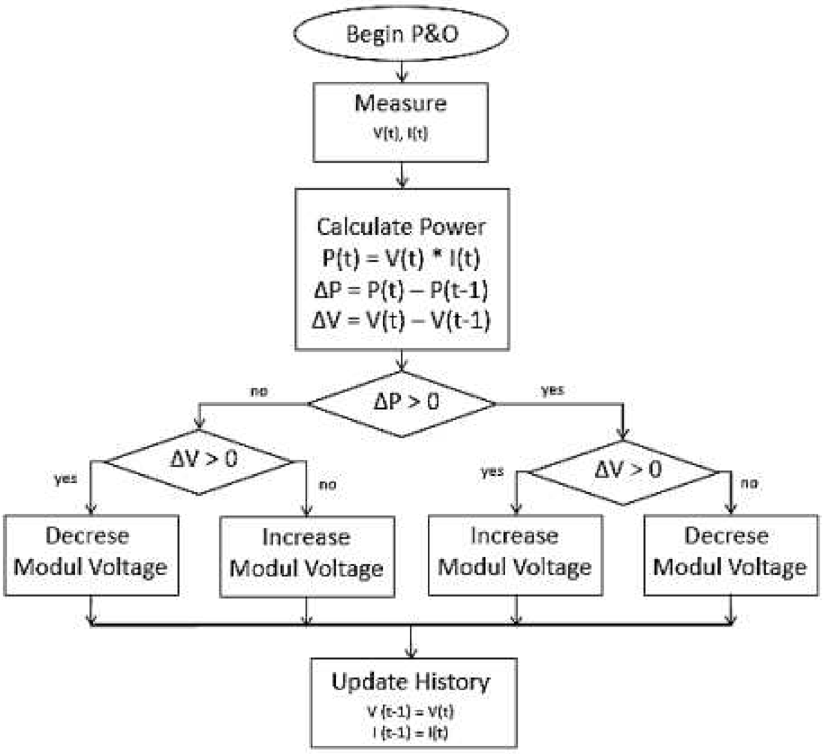

Figure 3. General Flowchart of P&O [5]

The control model of the system with a variable step size is shown in Figure 4. Referring to the study by Kolewora (2018), the first step involves setting the reference current values (IrefI_{ref}Iref) as aaa, bbb, and ccc under conditions step 1, 2, and 3. Then, the change in current (ΔIΔIΔI) due to changes in solar irradiation is calculated.

If the change in current is smaller than the reference current aaa (ΔI<3.5ΔI < 3.5ΔI<3.5), step 1 is executed, setting the step size to 0.01. If ΔI<6ΔI < 6ΔI<6, step 2 is

executed, setting the step size to 0.1. Finally, if ΔI<7.5ΔI < 7.5ΔI<7.5, step 3 is executed, setting the step size to 1.
The P&O algorithm with a modified variable step size is illustrated in Figure 4.

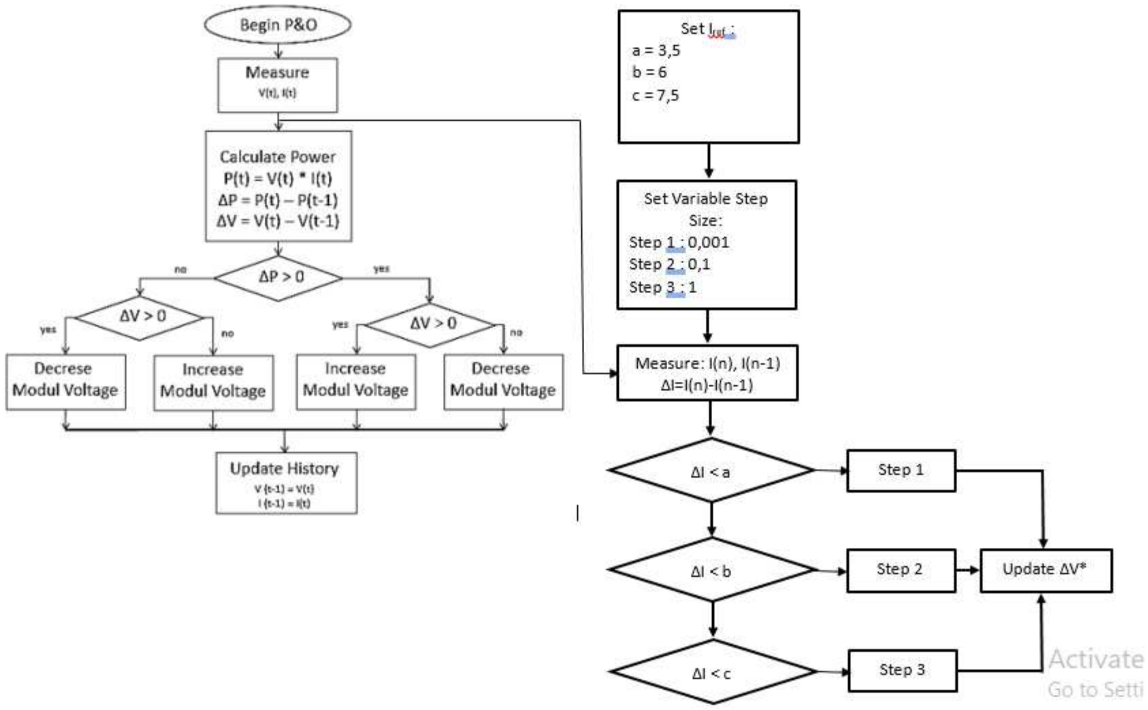

Figure 4. Modified P&O MPPT

This circuit model operates automatically by utilizing the change in current (dIdIdI) obtained from the PV system in response to changes in solar irradiation. This change can be represented by equation (1).

$$dI = I_{in}(n) - I_{in}(n-1) \tag{1}$$

The value is then compared with the reference current (IrefI_{ref}Iref) determined from equation (2).

$$set\ I_{ref} \begin{Bmatrix} a = 3{,}5 \\ b = 6 \\ c = 7{,}5 \end{Bmatrix} \tag{2}$$

Next, the step size (SS) value to be used is set, as shown in equation (3).

$$set\ SS = \begin{Bmatrix} SS1 = 0{,}01 \\ SS2 = 0{,}1 \\ SS3 = 1 \end{Bmatrix} \tag{3}$$

Then, a decision is made to select the appropriate step size (SS) based on the change in current (dI) obtained from the PV and compared with the reference current (IrefI_{ref}Iref) set in equation (2). The decision-making process can be expressed in equations (4), (5), and (6) as follows.

If dI < a, then step 1 ON (4)
If dI < b, then step 2 ON (5)
If dI < c, then step 3 ON (6)

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3. Results and discussion

After creating the model as shown in Figure 1, the next step is to verify the PV system by observing the output voltage characteristics and their response to changes in solar irradiation. The higher the solar irradiation, the greater the voltage value, resulting in a higher PV output power. At each level of irradiation, there is a specific point where the output power reaches its maximum.

Based on the verification results, it was found that at each solar irradiation level, there is a point where the output power is maximized. This aligns with the basic characteristics of PV as described in [5], [7], [6]. Subsequently, this point will be tracked by the MPPT P&O algorithm to ensure that the power generated by the PV is maximized.

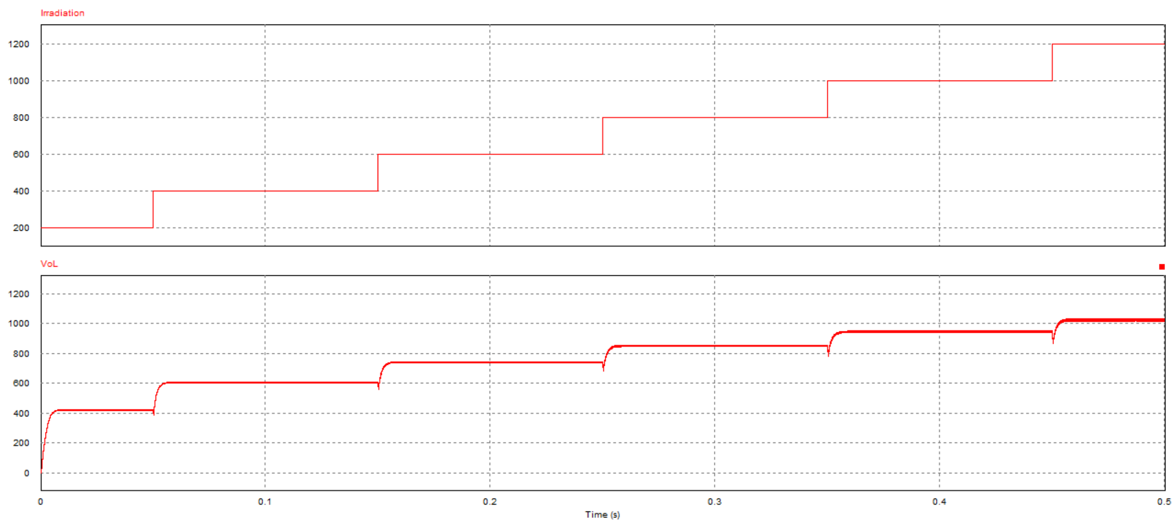

Figure 5. Output Voltage Curve Results Based on Solar Irradiation

1. Rooftop Solar PV System Analysis
a. Modeling Results of the Rooftop Solar PV System Using Conventional P&O MPPT

Efficiency testing of the output power on the Rooftop Solar PV System at PT. Hydratech Smart Indonesia's building was conducted to evaluate the overall success of the system in improving efficiency under varying irradiation levels using the Conventional P&O MPPT. This testing involved measuring the output power at different solar irradiation levels, ranging from 200 W/m² to 1200 W/m². The simulation results produced an output power curve as shown in Table 3.

Table 3. Conventional P&O MPPT

Iradiation	Ppv	Pmpp	Efficiency
200	713,53	581,94	81,56%
400	1492,85	1207,43	80,88%
600	2220,31	1806,21	81,35%
800	2930,71	2380,84	81,24%
1000	3613,08	2931,14	81,13%
1200	4259,89	3450,58	81,00%

b. Modeling Results of the Rooftop Solar PV System Using Modified P&O MPPT

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Efficiency testing of the output power using the Modified P&O MPPT follows the same concept as the conventional system, aiming to improve efficiency under varying irradiation levels. This test also involves measuring the output power at different solar irradiation levels, ranging from 200 W/m² to 1200 W/m². The testing time and irradiation variations used are consistent with the previous Conventional P&O MPPT test to ensure continuity in output power efficiency results.

The purpose of this test is to compare the output power (PoutP_{out}Pout) of the modified system with the conventional system for each variation. The simulation results produced an output power curve as shown in Table 4.

Table 4. Modified P&O MPPT

Iradiasi	Ppv	Pmpp	Efisiensi
200	555,16	410,23	73,89%
400	1495,34	1200	80,25%
600	2220,31	1971,63	88,80%
800	2930,15	2880,21	98,30%
1000	3618,57	3585,28	99,08%
1200	4057,30	3814,88	94,02%

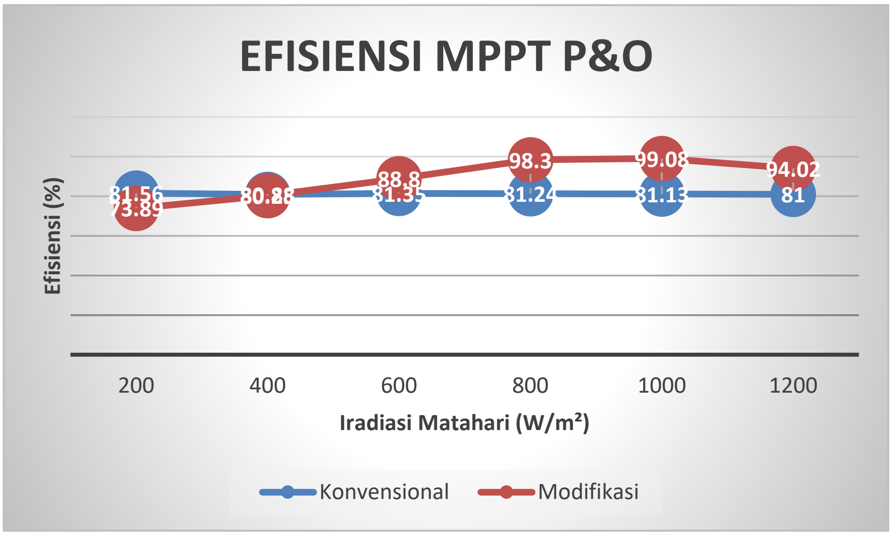

Figure 5. Comparison Chart of Efficiency Between Conventional and Modified P&O MPPT

4. Conclusion

Berdasarkan hasil simulasi dan analisis dari hasil pengujian dan pengamatan pada sistem PLTS Atap di Gedung PT. Hydratech Smart Indonesia dengan membandingkan algoritme MPPT P&O konvensional dan MPPT P&O modifikasi, maka diperoleh kesimpulan bahwa efisiensi daya output yang pada rangkaian MPPT P&O modifikasi lebih baik hasilnya jika dibandingkan dengan daya output pada rangkaian MPPT P&O konvensional. Persentase rata-rata yang dihasilkan sebesar 89,06% untuk modifikasi sedangkan 81,19% untuk konvensional.

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