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REDUCING OVER VOLTAGE ON SOLAR POWER PLANT WITH CONSTANT POWER GENERATION USING INCREMENTAL CONDUCTANCE MPPT

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Abstract

Although Indonesia is a tropical country with year-round sunshine, the use of solar energy as a solar power plant could be a feasible option. The power instability provided by solar panels is one of the challenges in the solar power plant system since it relies largely on irradiance and has low energy conversion efficiency. The Perturb and Observe (P&O) approaches are necessary to handle this problem because they require maximum control of Power Point Tracking (MPPT). This P&O MPPT control allows solar PV to perform at the MPP point, maximizing solar PV output power. However, even though the MPPT P&O control is operating at the MPP point, the output voltage to the load is simultaneously at its maximum, resulting in overvoltage. As a result, this paper discusses a variation of the MPPT Perturb and Observe (P&O) algorithm for Constant Power Generation (CPG), which combines MPPT P&O with power management settings to reach the solar PV's maximum limit. This method can set up two different solar PV working modes: MPPT mode and CPG mode. When the solar PV output power is less than the reference power, the MPPT mode is used to increase solar PV output power. When the solar PV output power is greater than or equal to the reference power, the CPG mode is used to limit the output power of the solar panels. The load output voltage response can be kept constant 48 V with less than 5% error, according to the simulated results of this MPPT-CPG control, which have been verified using a variety of irradiance and reference power. Further extension in this paper Incremental Conductance MPPT is used to reduce transient response and maintain the power stability.

Index term: Constant power generation (CPG), maximum power point tracking (MPPT) P&O, solar PV

I. INTRODUCTION

According to the National Energy Council, Indonesia's solar energy potential is 4.8 kilowatt-hours per square meter per day (kWh / m2 / day), or 112,000 GWp equivalent, when compared to the country's prospective land. Given the increasingly limited supply of fossil fuels, this has a lot of potential for usage as a solar power plant to meet electrical energy needs. The solar power plant system is turned into electrical energy utilising solar panels in solar energy. However, using solar PV as a solar power plant has a disadvantage: the power produced by solar PV is inherently unstable due to its dependence on irradiance. Furthermore, the energy conversion efficiency is modest (approximately 30%) [3], [11]. As a result, solar PV must use the MPPT approach and be forced to work at the MPP point [2], [5].

Nowadays, there is a lot of research being done on the MPPT approach using both traditional and artificial intelligence technologies. P&O is one of the most widely utilized traditional ways. This is due to the fact that P&O is simple to implement [3], [4], [7], [13], low cost [13], has a quick rise time [6], and produces high power efficiency. Because the MPPT P&O technique operates at maximum power, the output voltage to the load is also at maximum power, causing severe voltage disturbances because the voltage provided to the load is greater than the load rating voltage. Solar PV is forced to work on the MPP point by the MPPT P&O condition. This scenario can lead to overvoltage if irradiance changes occur. The MPPT is modified with a Constant Power Generation (CPG) to avoid this [5]. This MPPT P&O-CPG modification works to limit the maximum power generated by the MPPT P&O method, ensuring that the generated voltage is always at the rated level [8]. A DC-DC converter is required to use this MPPT P & O-CPG modification.

The SEPIC converter is utilized as a DC-DC converter. The SEPIC converter's duty cycle is always altered according to modified MPPT P & O-CPG with two modes, MPPT and CPG. When the PV output power (Ppv) is less than or equal to the reference power (Pref), the MPPT mode is used to optimize the power re-generated SEPIC converter [9]. When the PV output power (Ppv) reaches Pref in CPG mode, the PV output power (Ppv) is kept constant Ppv = Pref [9]. To test the performance of both MPPT P&O and CPG operations in preventing overvoltage by restricting PV output power, PSIM software was used to model solar modules with varying irradiation and load values. Further extension in this paper Incremental Conductance MPPT is used to reduce transient response and maintain the power stability.

CHARACTERISTICS OF PHOTOVOLTAIC MODULE

A. PV Equivalent Circuit Model

A photovoltaic module is made up of a group of solar cells that can convert sunlight into electrical energy [11]. An ideal current source, series resistance, and parallel resistances can be used to represent a PV module. The direct current created by the ideal source of current sources is comparable to

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the solar cell's light irradiation. Drop voltage and leakage current measurements are presented by resistance series and parallel resistance [4]. Figure 1 depicts the photovoltaic cell's equivalent circuit. With [3], [6], [7], [11], [12], [13], characteristic equations for the current and voltage of solar modules are constructed based on a single diode model: Based on the Shockley and Queisser diode equation, the Ipv−Vpv characteristic equation of a PV cell is given by

$$I_{pv} = I_{ph} - I_0\left[\exp\left(\frac{V_{pv} + R_s I_{pv}}{nV_T}\right) - 1\right] - \frac{V_{pv} + R_s I_{pv}}{R_p} \qquad (1)$$

Where Iph is the current generated by the incident solar radiation, I0 is the reverse saturation or leakage current of the diode; it is given by the following expression

$$I_0 = \frac{I_{cc}}{\left[\exp\left(\frac{V_{co}}{nV_T}\right) - 1\right]}$$

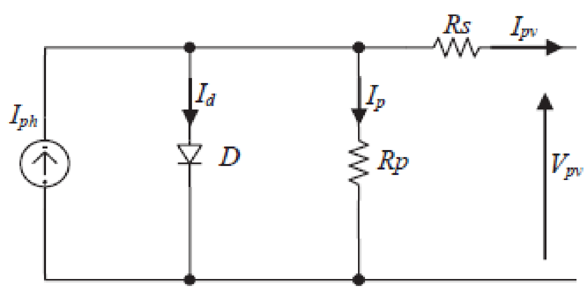

Fig. 1. Equivalent circuit of the photovoltaic cell [3]

Rs are the intrinsic series resistance of the solar cell, Rp is the equivalent shunt resistance of the solar array (its value is usually very larged) and VT is the thermal voltage of the PV module, it is given by the following equation:

$$V_T = \frac{KT_c}{q}$$

Where K is the Boltzmann constant (K=1.38×10−23 J/K), q is the electron charge (q=1.6×10−19 C), Tc is the absolute temperature in Kelvin, and n is the diode ideality factor (1 < n < 1.5). In this work, two solar panels were employed, each with a capacity of 100 WP, and they were connected in series. Table I displays the electrical properties of the photovoltaic module when operating under optimum conditions (ambient temperature of 25 ° C. and radiation of 1000 W/m2).

TABLE I. PHOTOVOLTAIC MODULE PARAMETER AT 25°C AND 1000 W/M2

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Polycrystalline Photovoltaic Module	
Parameter	**Value**
Maximum Power (Pmp)	200 W
Maximum Power Current (Imp)	5.62 A
Maximum Power Voltage (Vmp)	35.6 V
Short Circuit Voltage (Isc)	6.4 A
Open Circuit Voltage (Voc)	43.8 V

B. PV Characteristic Curve

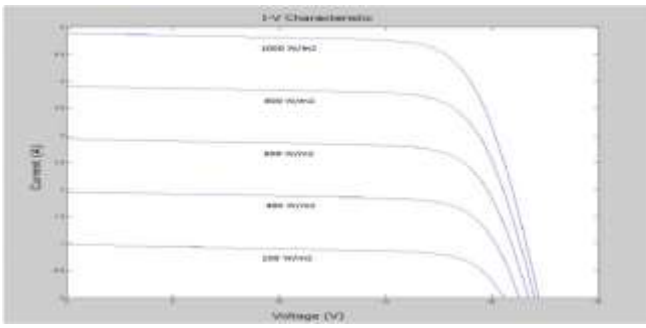

Fig. 2. Current-Voltage (I-V) characteristics with variable irradiation [6]

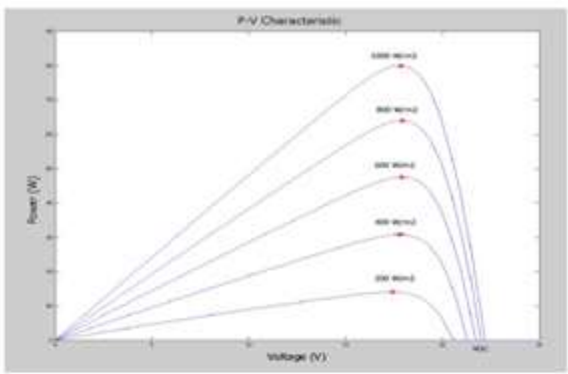

Fig. 3. Power-Voltage characteristics (P-V) with variable irradiation [6]

A characteristic curve for solar cells shows the relationship between current and output voltage (I-V curve) and power and output voltage (P-V curve) (P-V curve). The current photovoltaic-voltage (I-V) and power-voltage (P-V) characteristic curves are shown in Figs. 2 and 3 with an irradiation value change of 200-1000 W/m2. Figure 2 illustrates that as the irradiance increases at a constant temperature of 25°C, the output current increases as well. Figure 3 demonstrates that as irradiance increases at a constant temperature of 25°C, PV power increases and furthermore.

SEPIC TYPE DC-DC CONVERTER

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SEPIC (Single-Ended Primary Inductance Converter) is a derivative converter of the Buck-Boost converter. The output voltage of a SEPIC converter can be larger or smaller than the input voltage without changing the polarity [10]. The characteristics of a SEPIC converter are as follows:

1. Both inductor values are very large, resulting in a more steady current generation.
2. Both capacitor values are very large and the resulting voltage is more constant/stable.
3. Network in steady-state, meaning that the voltage and current waveforms are periodic.
4. The ratio of duty cycle D, when the switch closes DT, and when the switch opens (1-D) T.
5. Switches and diodes in ideal conditions.

Figure 4 depicts the SEPIC converter's power series, which includes power switches K (MOSFET transistor), SEPIC inductors L1 and L2, filter capacitors C1 and C2, diode D outputs, and load resistor R Load. Setting the duty cycle value as shown in equations 2 and 3 determines the SEPIC converter's large output value. The duty cycle (D) is a time comparison between when the switch is on and when it is switched off.

$$D = \frac{Vo}{Vo+Vs} \quad (2)$$

$$Vo = Vs\frac{D}{(1-D)} \quad (3)$$

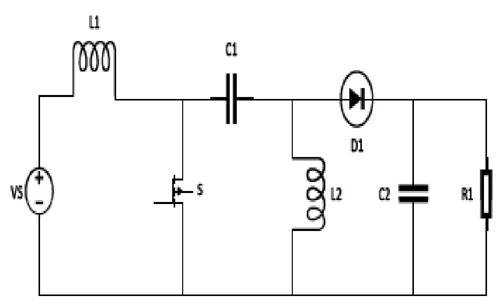

Fig. 4. The power series of SEPIC converter

II. PROPOSED METHOD

A. Design Configuration System

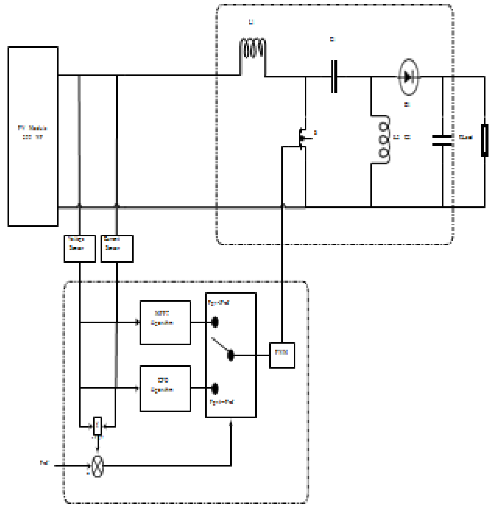

Fig. 5. Block diagram operational principles MPPT P&O-CPG.

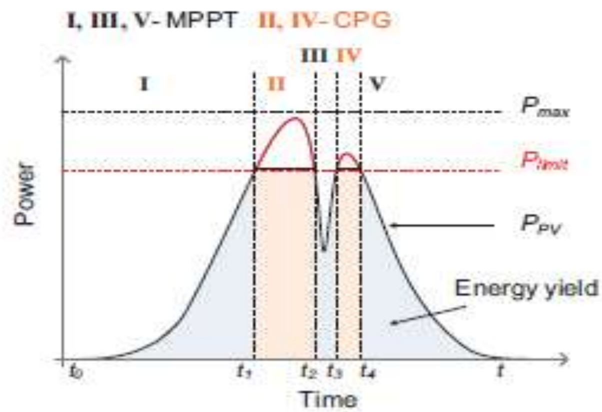

Fig. 6. Areas of operation for MPPT and CPG modes in the PV system for a day [8]

In this system, a solar PV 200 WP related SEPIC converter is used with a variable resistive load of 48 Volts, as shown in Fig. 5. (0-200 Watts). Two voltage sensors and two sensors are fitted on both the input and output sides of the SEPIC converter. The current and voltage sensor on the SEPIC converter's input side is used to supply voltage and current information to the MPPT P&O-CPG control algorithm system. The current and voltage sensors on the SEPIC converter's output side are used to monitor the voltage and load output power, depending on whether the MPPT P&O or CPG control modes are active. MPPT P&O-CPG operational principles depicted in Fig. 5. It can be divided into two modes:

a) MPPT P&O mode (Ppv <= Pref), where the MPPT P&O algorithm should track maximum power and oscillate around the MPP.

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b) CPG mode (Ppv > Pref), where PV output power is limited to Pref. In this CPG mode, PV voltage continuously interrupted a point called Constant Power Point (CPP) (Ppv = Pref). Figure 6 shows the areas of operation for MPPT and CPG modes in a PV system for a day.

B. Design of MPPT P&O-CPG

P&O-CPG has two modes when using the MPPT method: MPPT mode and CPG mode. Two factors are used to determine which mode is activated: solar panel output power (PPV) and reference power (Pref). The current sensor readings and the voltage on the solar panel output are used to calculate the output power of the solar panel. The boundary power is the reference power that is inputted. When PPV is equal to or more than Pref, MPPT mode is enabled, and when PPV is greater than or equal to Pref, CPG mode is enabled. The duty cycle of the SEPIC converter will be determined by this active mode. As a result, the generated loads are protected from the failure of excess voltage by this control mechanism. Figure 7 depicts the MPPT P&O-CPG system's flowchart.

In this study, the MPPT P&O approach for MPPT mode was examined. By obtaining the current-voltage and data on the solar panels through the current sensor and voltage on the input SEPIC converter, the MPPT P&O method compares the output power while being measured and previously to be transformed into a duty cycle. If the PV output power varies due to increasing voltage changes ($dP/dV > 0$), the operating voltage of the solar panels is perturbed in the same direction to bring it closer to the MPP. The direction of the perturbation is reversed if the power change output to a change in voltage is lowered ($dP/dV < 0$).

This procedure is done until the MPP is achieved [3]. After that, the system oscillated around the MPP. Figure 8 depicts the MPPT P&O Flowchart technique. The modified flowchart of the P&O algorithm MPPT is shown in Fig. 9. Both modified MPPT P&O methods are nearly identical to the original MPPT P&O method, except that the Vref value in the modified MPPT P&O method is in the opposite direction. This strategy allows the MPP to manage the feed-in power on changeable resistive loads by forcing the solar PV operation to the left of the MPP.

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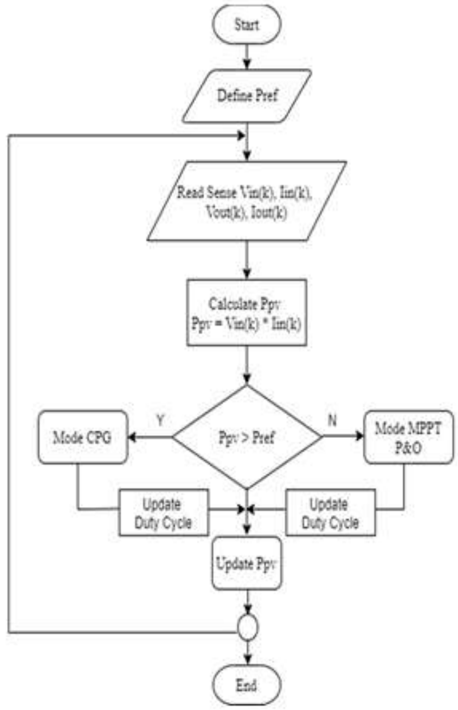


Fig. 7. Flowchart of MPPT P&O-CPG system

III. SIMULATION RESULT

A. Simulation Circuit

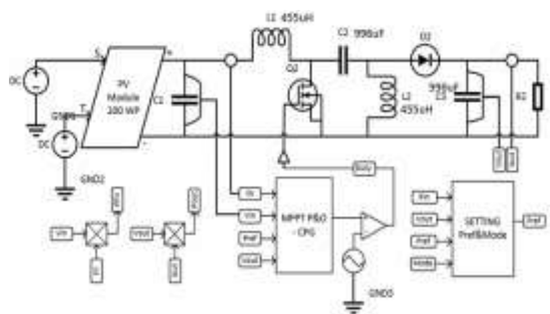


Fig. 8. Simulation circuit for MPPT P&O-CPG

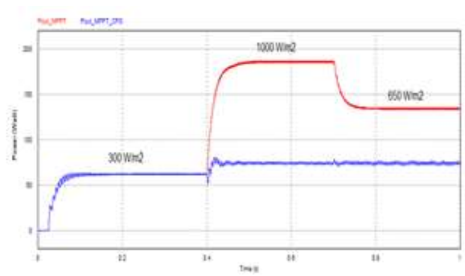
TABLE II. DESIGN OF SEPIC CONVERTER

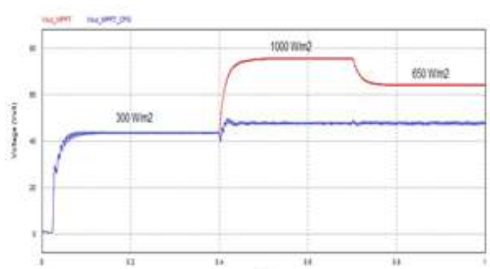
Terms	Values
Input voltage	35.6 Volt
Input current	5.62 Ampere
Output voltage	48 Volt
Output current	3.3 Ampere
Frequency switching	40 kHz
Size capacitors (C1 and C2)	996 uF
Size inductors (L1 and L2)	455 uH

The complete simulation circuit of the system using the MPPT P&O-CPG approach based using the PSIM software, in which the DC-DC SEPIC converter is utilized to connect the solar PV module 200WP to a variable resistive load is shown in Figure 10. In Table I, the solar PV module's parameters are tabulated. Table II tabulates the capacitor design size and inductor of the SEPIC converter. B. Result Simulation Simulated testing was carried out to determine the performance of the proposed MPPT P&O-CPG technique utilising three different reference power (Pref) values (75W, 150W, 200W) and three different irradiance values (300 W/m2, 650 W/m2, 1000 W/m2) at the same temperature of 25°C. The results of the response MPPT P&O-CPG technique are then compared to the results of the response MPPT P&O method. Table III shows the load resistor calculation for the reference power (Pref) listed above.

TABLE III. THE CALCULATION OF THE LOAD RESISTOR

Power (W)	Voltage (V)	Current (A)	Resistor (Ohm)
75	48.8	1.042	30.72
150	48.8	2.083	15.36
200	48.8	3.472	11.52





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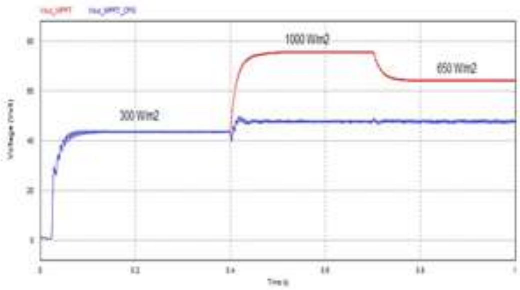

Fig. 9. Comparison of Pout (W), Vout (V) and Iout (A) response with 75W load when using MPPT P&O method and MPPT P&O-CPG method

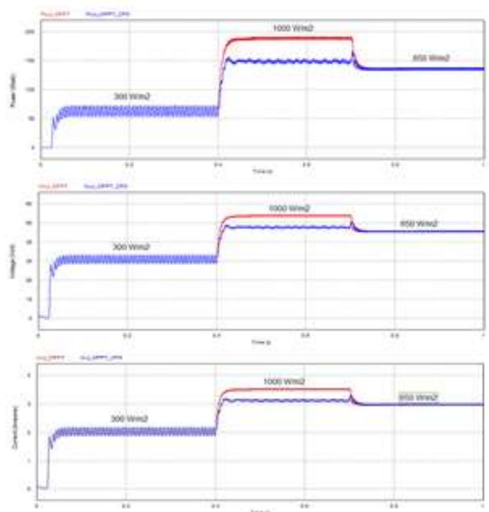

Fig. 10. Comparison of Pout (W), Vout (V) and Iout (A) response with 150W load when using MPPT P&O method and MPPT P&O-CPG method

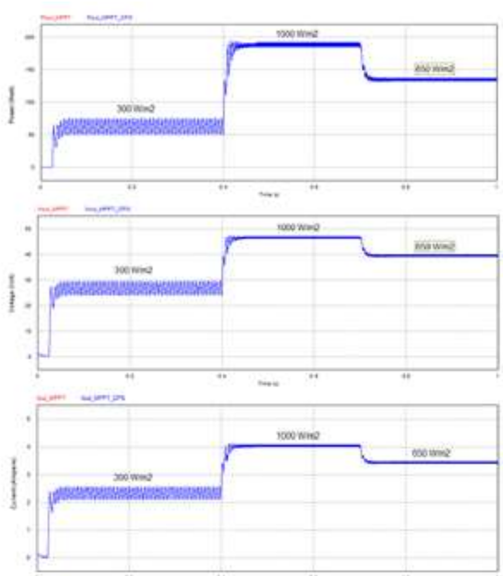

Fig. 11. Comparison of Pout (W), Vout (V) and Iout (A) response with 200W load when using MPPT P&O method and MPPT P&O-CPG method

Incremental Conductance MPPT:

Further extension in this paper Incremental Conductance MPPT is used to reduce transient response and maintain the power stability. The incremental conductance (INC) maximum power point tracking (MPPT) approach is used to generate steady, maximum, and continuous energy from the PV array. At the point of common connectivity, additional services such as current harmonics mitigation, voltage harmonics reduction, and reactive power support are also provided (PCI). The PV system's ability to extract maximum power is critical. As a result, the literature has devised and discussed several MPPT (Maximum Power Point Tracking) methodologies.

Fig. 12. Comparison of Pout (W), Vout (V) and Iout (A) response with 200W load when using MPPT INC method

CONCLUSION

In this paper, we propose the MPPT P&O-CPG method to be able to control solar panels that work on 2 conditions i.e. in MPPT operations and CPG operations to avoid overvoltage on the load. This MPPT P&O-CPG method has been evaluated through a PSIM simulation. Simulated results indicate that the MPPT mode is identified when the load requirements are greater or equal to the solar power panel (PPV < = Pref) and the voltage on the output side of the < 48V. While CPG mode The MPPT P&O-CPG approach has been shown to avoid excessive voltage with a control error limit of less than ± 5% of the load's rating voltage, albeit it is still overshot during mode changeover due to irradiance changes. Further, Incremental Conductance MPPT is employed to lessen transient response and preserve power stability in this paper. The In C algorithm improves tracking time and produces more energy when there is a considerable irradiation change.

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