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Development of Solar Maximum Power Point Tracking Algorithm for Multiple Angle Condition

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Abstract: Due to its clean and limitless nature, photovoltaic (PV) energy is one of the most significant energy sources. However, low energy conversion efficiency and high installation costs are two drawbacks of PV or solar panels. The improved efficiency of PV can be obtained by attempting to make the panel run at its maximum power point (MPP). It also the objective of this work to compare the performance between Perturb & Observe (P&O) algorithm and Incremental Conductance (InC) algorithm for multiple angle condition. This work used P&O and InC algorithm as the system in the MPPT. The angle of the solar panel manually been adjusted. Boost converter work be act as the MPPT structure while the algorithm would be run using Arduino. The angle been used in the indoor practical are $0°$, $25°$ and $55°$. The indoor experiment be run because of outdoor condition that unstable within period of run testing. All situation shown that both systems work properly by the increasing of the output voltage the average output power when using P&O algorithm are higher than when using InC algorithm. This be shown at almost every angle of the solar panel that is $0°$, $25°$ and $55°$. The average output power at $0°$ and $55°$ for P&O were higher than InC while at $25°$ are slightly lower than InC. From the result, it could be concluded that the P&O algorithm give a higher average output power than InC algorithm. This happen because of time used for InC to reach nominal peak are longer than P&O. For future work, a microcontroller to control the tilt angle with the aid of a motor while also doing this at outdoor condition with having 2 prototypes to both each algorithm simultaneously.

Keywords: MPPT, Incremental Conductance (InC) algorithm, Perturb & Observe (P&O) algorithm

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1. Introduction

Due to its clean and limitless nature, photovoltaic (PV) energy is one of the most significant energy sources. PV or solar panels capture the energy from the sun and convert it into electric energy using direct current (DC). However, the weakness of this device is it has low energy conversion rate. The low energy conversion efficiency of the PV is because of the changes of sun's irradiation and temperature One of the cause of the change of irradiation are shading conditions and partial conditions. Initially of the instalment of PV, there were no solution to this problem but after a few years there some researchers have introduced various algorithm techniques [1]. The improved efficiency of PV can be obtained by attempting to make the panel run at its maximum power point (MPP)). It can be achieved by utilizing a DC-DC boost converter.

There are several algorithm techniques that has been conducted by researchers to optimize PV such as Constant voltage control, Perturb & Observe (P&O), Incremental Conductance (InC) and Fuzzy Logic [2]. Even though, P&O method is widely used than the others due to it's simple coding but the other techniques offer a better performance than P&O method [3]. Boost converter is normally use in a MPPT system. Boost converters generate an output voltage that varies based on the duty cycle, either higher or lower. In this project, a boost converter will be used to compare between the two algorithms such as P&O and InC in term of system efficiency by setting the solar panels at different angles.

The objective of this project is to build a prototype of Solar MPPT for Multiple Tilt Angle. The second objective is to compare the performance between P&O and InC algorithm. The scope of this project is specification for 5W Solar panel. Next using P&O and InC algorithm technique. The angle of solar panel would be manually adjusted. Lastly, this project be done indoors using LED Flood Light (50W) that act as the supply.

1.1 Boost (Step-Up) converter

Step-up circuits are used to produce voltages that are greater than the input voltage. It's known as a boost. The polarities perfectly match those of the input. Figure 1 shows the basic circuit of boost (Step-Up) converter.

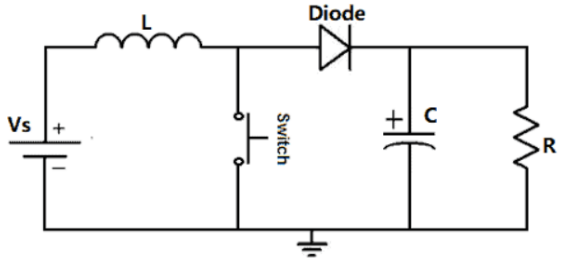

Figure 1: Boost (Step-Up) Converter Circuit

An inductor is connected to the input voltage source. The switch-capable solid-state device is linked across the source. A diode is utilised as the second switch. As seen in the Figure 1.1, the load and the diode, which is coupled to a capacitor, are connected in parallel.

Since the input source's connected inductor produces a constant input current, the boost converter is regarded as the constant current input source. As a source of continuous voltage, the load may also be considered. The controlled switch's on/off operation is regulated via pulse width modulation (PWM). PWM can be time- or frequency-based. Frequency-based modulation has the disadvantage of requiring a broad frequency spectrum to operate the switch and produce the desired output voltage. The primary use of time-based modulation is in DC-DC converters. It is simple to construct and use. This particular PWM modulation keeps the frequency constant.

2. Materials and Methods

2.1 Flowchart for algorithm

Perturb and Observe (P&O) algorithm flowchart as shown in Figure 2.

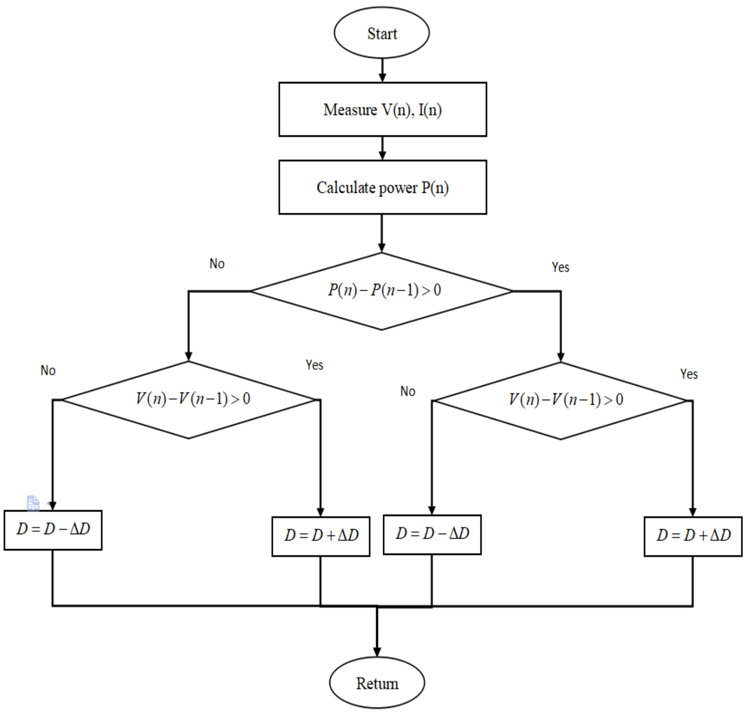

Figure 2: Flowchart for P&O Algorithm [4]

The processor will calculate the present power Pnew and contrast it with the power Pold that was previously measured. PWM duty cycle is increased to maximise PV panel output when Pnew is more than Pold; duty cycle is decreased to return the system to its maximum power when Pnew is less than Pold. This MPPT algorithm is straightforward, simple to use, affordable, and accurate.

The foundation for P&O MPPT algorithm is the constant measurements of fluctuations in the power and voltage of the PV module. If both the power and voltage changes are positive, the ideal point must be to the right of the operational point. Next, the reference voltage is adjusted to correspond to the ideal point. If the power change is negative and the voltage change is positive, the ideal point must be to the left of the operational point. The reference voltage is set to its optimum value in this situation. Once the reference voltage that corresponds to the ideal point has been determined, the control unit adjusts the duty cycle to regulate the PV voltage. In reaction to variations in radiation or temperature that have an impact on where the MPP is located, this procedure is continually carried out. Once the ideal point has been determined, the MPPT algorithm oscillates around it. The voltage reference should be adjusted with a variable step size in order to reduce these oscillations.

Incremental Conductance (InC) algorithm flowchart as shown in Figure 3.

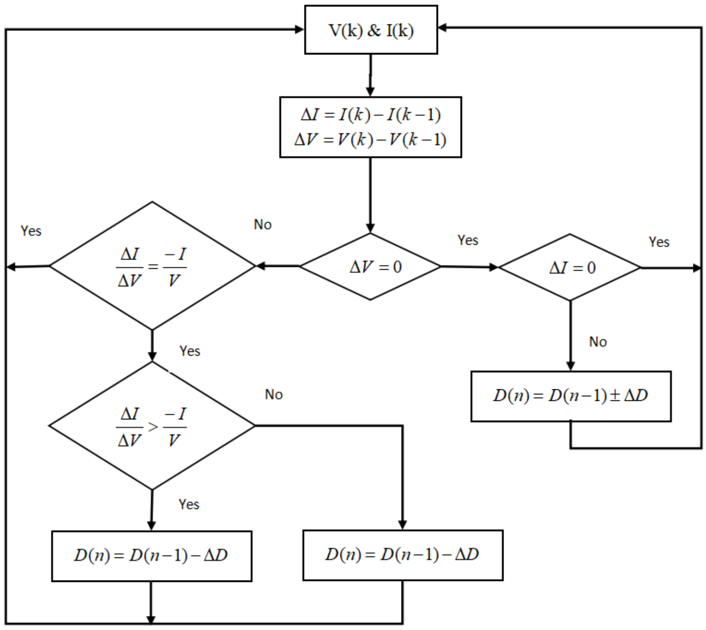

Figure 3: Flowchart for InC Algorithm [4]

The InC algorithm determines the P-V curve's slope, and then searches for the MPP at the P-V curve's peak. For MPPT, this approach uses the incremental conductance dI/dV and the instantaneous conductance I/V. Based on the correlation between the two data, the P-V curve's operating point for the PV module may be located, as described in Eq. (1) – (3). For example, (1) indicates that the PV module operates at the MPP, while Eq. (2) and (3) indicate that it operates on the left and right sides of the MPP in the P–V curve, respectively.

$$\frac{d_i}{d_v} = -\frac{I}{V} \qquad \text{Eqn. (1)}$$

$$\frac{d_i}{d_v} > -\frac{I}{V} \qquad \text{Eqn. (2)}$$

$$\frac{d_i}{d_v} < -\frac{I}{V} \qquad \text{Eqn. (3)}$$

Curve of P-V has a slope of zero:

$$\frac{d_p}{d_v} = 0 \qquad \text{Eqn. (4)}$$

The equation shown below is obtained by rewriting (4):

$$I + V\frac{d_i}{d_v} = 0 \qquad \text{Eqn. (5)}$$

PV module V and I are measured by the MPPT controller.while (5) is used to detect the MPP in the typical incremental conductance algorithm. The converter's duty cycle must be reduced if condition (2) is met, and vice versa if condition (3) is met. If condition (5) is met, however, there must be no change in the duty cycle [5].

Component calculation for boost converter design for PV system in Matlab in Table 1.

Table 1: Component Values for Boost Converter

UNITS	VALUES
Vmp_{1000}	17.5 V
Vmp_{25}	15.75 V
Dmp_{1000}	0.843
Dmp_{25}	0.368
Vi	0.035 V
Vo	0.223 V
Ri	$716.55\Omega \approx 800\Omega$
Ro	$2476.4\Omega \approx 3000\Omega$
Io	$4.024 \times 10^{-3} A$
fs	25000Hz
Cin	$94.1176\mu F \approx 100\mu F$
Co	$27.2233\mu F \approx 30\mu F$
L	$28.81mH \approx 30mH$

Figure 4 shows the modelling of MPPT Circuit Connection in Matlab.

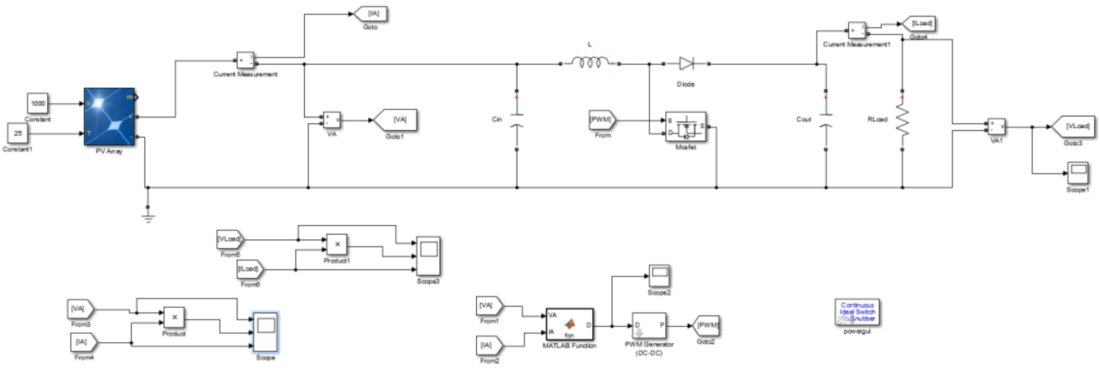

Figure 4: MPPT Circuit Connection in Matlab

3. Results and Discussion

The results shown are the data that been collected when doing the project as simulation and hardware development.

3.1 Simulation result

Figure 5 and 6 show output of P&O algorithm and InC algorithm, respectively.

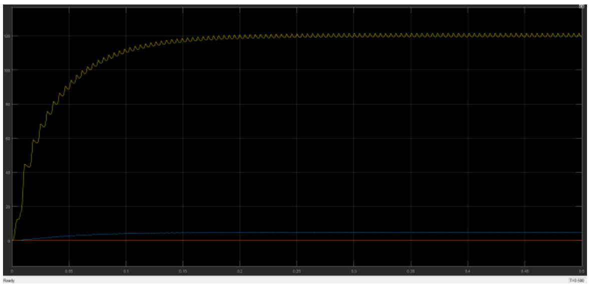

Figure 5: Output graft for P&O algorithm (Yellow = Vo, Red = Io, Blue = Po)

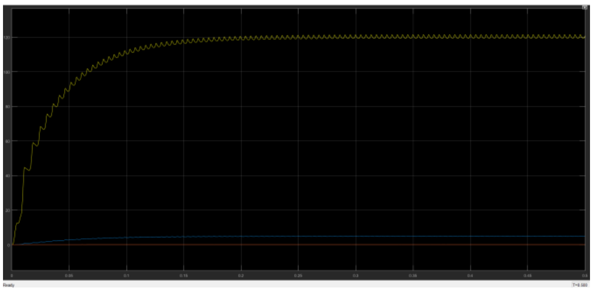

Figure 6: Output graft for InC algorithm (Yellow = Vo, Red = Io, Blue = Po)

Table 2 and 3 show that the power losses for P&O algorithm are lesser than the InC. So, it could be concluded that P&O algorithms are more efficient than InC algorithm.

Table 2: Output Power Comparison between 0.25s to 0.27s

	P&O algorithm, Po (W)	Incremental Conductance algorithm, Po (W)
The average Po	=4.8003 W	=4.7943 W
Power Losses	5W - 4.8003W =0.1997W	5W - 4.7943W =0.2057W

Table 3: Output Power Comparison between 0.271s to 0.291s

	P&O algorithm, Po (W)	Incremental Conductance algorithm, Po (W)
The average Po	=4.8057W	=4.8017 W
Power Losses	5W - 4.8057W =0.1943W	5W - 4.8017W =0.1983W

3.2 Hardware development

Figure 7 shows the testing of hardware at $0°$, $25°$ and $55°$ positions.

Figure 7: Hardware development at $0°$, $25°$ and $55°$.

Figure 8 shows the result for both algorithm that are P&O and InC algorithm when the solar panel at position $0°$. From the results, it could be see that the difference of Vout and Vin are positive. It shown that both hardware development system work correctly with the Vout is higher than the Vin. So from both algorithm, P&O algorithm shown the best performance by have a higher average output power with 2.692W than InC 2.443W.

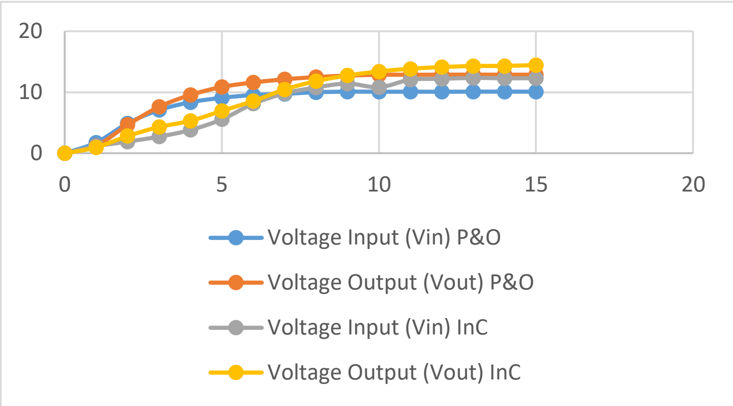

Figure 8: Graph of voltage input and output for P&O and InC algorithm at $0°$

Figure 9 shows the result for both algorithm that are P&O and InC algorithm when the solar panel at position $25°$. From the results, it could be see that the difference of Vout and Vin are positive. It shown that both hardware development system work correctly with the Vout is higher than the Vin. So, from both algorithms, InC algorithm shown the best performance by have a slightly higher average output power average output power with 3.911W than P&O 3.905W.

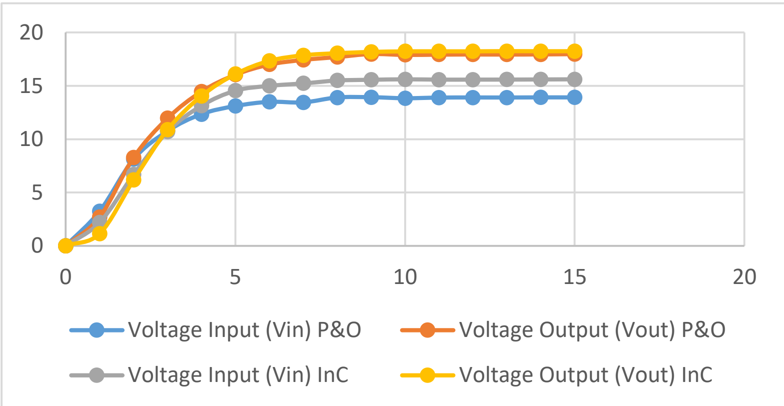

Figure 9: Graph of voltage input and output for P&O and InC algorithm at $25°$

Figure 10 shows the result for both algorithm that are P&O and InC algorithm when the solar panel at position $55°$. From the results, it could be see that the difference of Vout and Vin are positive. It shown that both hardware development system work correctly with the Vout is higher than the Vin. So from both algorithm, InC algorithm shown the best performance by have a higher average output power with 3.759W than InC 2.994W.

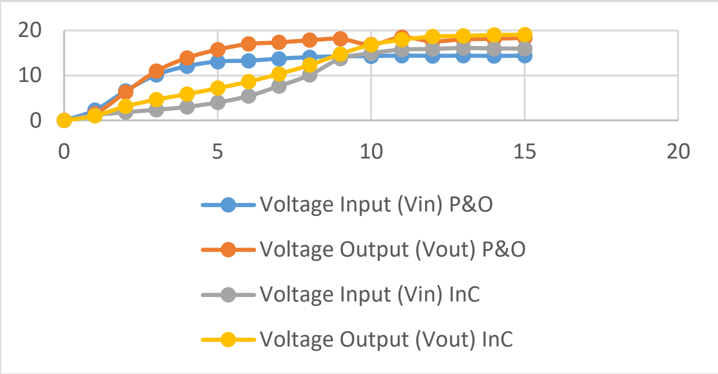

Figure 10: Graph of voltage input and output for P&O and InC algorithm at $55°$

Based on the Table 4, it is shown that the voltage difference between Vout and Vin are increasing for both algorithm for every angle. Besides that, the average output power when using P&O algorithm are higher than when using InC algorithm. This be shown at almost every angle of the solar panel that is $0°$, $25°$ and $55°$. The average output power at $0°$ and $55°$ for P&O were higher than InC while at $25°$ are slightly lower than InC.

From the result it could be concluded that the P&O algorithm give a higher average output power than InC algorithm. This happens because of time used for InC to reach nominal peak are longer than P&O.

Table 4: Comparison between P&O and InC algorithm at all condition angle

	P&O			InC		
	0°	25°	55°	0°	25°	55°
Highest voltage difference (V)	2.799	4.071	4.113	2.584	2.667	3.171
Time used to reach nominal peak (s)	10	9	10	12	9	13
Average output power (W)	2.692	3.905	3.759	2.443	3.911	2.994

4. Conclusion

Overall, in this project, the MPPT system used both algorithm is successfully developed according to specific dimensions in two and three-dimensional. Based on the result showed that MPPT system have the ability increase the performance of the solar panel. P&O algorithm system a better performance than InC algorithm almost at every tilt angle. This were because of P&O used a shorter time to reach the nominal peak than when using InC. Therefore, to improve the experiment, it could be built 2 prototype so each prototype could save each P&O and InC algorithm. By having 2 prototypes, the experiment could be done as an outdoor experiment. A temperature element could be added into the experiment. We could test the effect of temperature that could give to both algorithms.

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