Maximum Power Point Tracking With Improved Incremental Conductance Method for Fast Changing Solar Irradiation Level

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Abstract. This paper proposed an improved incremental conductance method to track the Maximum Power Point (MPP) for PV Panel under fast changing solar irradiation. When there is increment in solar irradiation level, the conventional incremental conductance method is confused and responses incorrectly. The proposed method response correctly and there is no steady state oscillation compared to the conventional method. Matlab simulation is carried out for both the improved and conventional incremental conductance method under fast changing solar irradiation level. The simulation results showed the system able to track the MPP faster than the conventional method.

1. Introduction
Solar energy has been highly used for electricity generation in the recent past. However, solar energy is an unstable energy source due to the dependence on the surrounding conditions such as the solar irradiation level. Hence, a control system call Maximum Power Point Tracking (MPPT) system has been developed. Varies types of controlled algorithm implemented in the MPPT system to extract the maximum power available from the Photovoltaic (PV) panel.

Some of the MPPT algorithms are Fractional Open-circuit Voltage (FOCV), Fractional Short-Circuit Current (FSCC), Fuzzy Logic, Neural Network, Hill Climbing (P&O), Incremental Conductance and many others [1, 2]. Among all the methods, Hill Climbing or P&O and incremental conductance methods are highly used. These two methods need a DC-DC converter in between the PV panel and load. Then, the MPP is tracked by tuning the duty cycle of the converter. P&O perturb the duty cycle of the converter to find the maximum power of the PV panel [3-5]. After the maximum power is found, the perturbation keeps on going and there is oscillation around the MPP. Meanwhile for Incremental Conductance method [6], the slope of the PV’s power against voltage (P-V) curve is used to track the MPP. The PV panel operates at the MPP when the slope of the P-V curve is equal to zero. Incremental conductance method varies the duty cycle of the converter to obtain the zero value in the slope of P-V curve.

In nature, it is rarely to obtain the zero value in the slope of P-V curve for incremental conductance as discussed in [7]. Hence, there is also steady state oscillation in incremental conductance method. Besides, this method is confused by the increment in solar irradiation level and responses incorrectly in the first response. In this paper, an improved incremental conductance algorithm is proposed to overcome the two weaknesses of conventional incremental conductance algorithm which are zero state oscillation and confusion during the increment of solar irradiation level.
2. PV Panel Characteristic

Single diode PV cell as shown in Figure 1 is used in this paper to model the PV panel [8].

![Figure 1. Equivalent Circuit of the PV cell](image)

![Figure 2. I-V Curve and P-V curve of PV panel](image)

PV panel consists of series or parallel connection of PV cell and the power generated depends on the solar irradiation level. Two important characteristic curves needed in describing the PV characteristics which are current against voltage (I-V) curve and power against voltage (P-V) curve as shown in Figure 2.

Under different level of solar irradiation level, the PV panel produces different level of power. When the PV panel is connected to the load, power is consumed by the load and a load line is imposed onto the I-V curve. PV panel current and voltage is the intersection point of the load line and I-V curve. Then, the PV power is simply the multiplication of current and voltage of the PV panel. MPPT algorithm is used to ensure the PV panel always supplies the maximum power or the load line always crosses MPP in the IV curve.

3. Weakness of Conventional Incremental Conductance Algorithm

In theory, conventional Incremental Conductance method stops the tuning of duty cycle when the MPP is reached. However in real life, it is rarely achieved due to the truncation error of the numerical differentiation and thus there is steady state oscillation.

![Figure 3. I-V and P-V curve of solar irradiation 1000W/m² and 400W/m²](image)

![Figure 4. Flow Chart of proposed Incremental conductance Algorithm](image)

Other than that, the conventional method responses incorrectly when the solar irradiation increases. At irradiation level of 400W/m² as shown in Figure 3, the duty cycle of the converter is tuned to obtain Load Line 2 and tracks the MPP (point B). Then, the solar irradiation increases to 1000W/m², but at this moment, the duty cycle of the converter still at Load Line 2, and point G is found by Load Line 2 in I-V curve which corresponds to the power at Point C in the P-V curve. The gradient between point B and C is calculated and it is a positive gradient. In fact the power found by the Load Line 2 is at Point C, the gradient between point C and the MPP (point A) of 1000W/m² P-V curve is in negative value. Hence the gradient value calculated by conventional method just after the increment in solar irradiation is incorrect and thus responses incorrectly in the first step.
4. Proposed Incremental Conductance
There are two main disadvantages in the conventional method, which are the steady state oscillation and also the confusion when the solar irradiation level increases. The shape of the P-V curve is used by incremental conductance method and the shape is affected by the solar irradiation level and the load resistance. Then, the algorithm uses the current and voltage value of PV panel in the calculation. So a well consideration needed on the effect of the solar irradiation and load changes against the current and voltage value of PV panel.

Table 1. Changes in PV voltage and current during the change of solar irradiation and load resistance

| Solar Irradiation | Voltage changes (dV) | Current changes (dI) |
|-------------------|----------------------|----------------------|
| Increase          | Increase             | Increase             |
| Decrease          | Decrease             | Decrease             |

| Load Resistance   | Voltage changes (dV) | Current changes (dI) |
|-------------------|----------------------|----------------------|
| Increase          | Increase             | Decrease             |
| Decrease          | Decrease             | Increase             |

Table 1 summarize the responses of PV panel voltage and current value against the changes on the solar irradiation level and load resistance. Refer to Figure 3, when the MPP is tracked at point F, then the solar irradiation suddenly increases, the system operates at point G. So, both of the voltage and current value increased. Conversely, when the MPP point E is tracked, and the solar irradiation suddenly decreased, then the system operates at point H, and both the voltage and current value decreased. These two types of changes are not well considered in the conventional incremental conductance algorithm. Meanwhile, when PV system operates at Load Line 1 and the load resistance increases causes the PV system to operate at Load Line 2. So, the PV voltage increases and current decreases. Vice versa, the PV voltage decreases and current increases when the load resistance decreases. Besides, a permitted error is applied to eliminate the steady state oscillation and equation (1) is used. Figure 4 shows the flow chart of the proposed method.

\[ |I + V(dI/dV)| < 0.06 \]  

(1)

5. Simulation Results
Matlab Simulink used to model the whole MPPT system consists of The PV panel model, SEPIC converter and MPPT controller. The PV panel model designed follows the Kyocera PV panel KC85T module.

The simulation is conducted for both algorithms to investigate the differences between the conventional and proposed incremental conductance algorithm. The duty cycle’s step size of the converter is set to be 0.005 and the MPPT controller sampling time is 0.05s. Figure 5(a) shows the simulation results of the conventional incremental conductance method. At the beginning, the solar irradiation is set to be 0.8 kW/m², then at t=0.2s, MPP is reached and the duty cycle fluctuates between 0.61 and 0.62. PV power also oscillates. At t=0.716s, the solar irradiation is increased to 1.0kW/m², but the duty cycle still at 0.62, then the power of the PV panel increases. At t=0.75s, the MPPT controller is sampling and it is confused, hence the incorrect duty cycle value changes incorrectly and the power of the PV panel is decreased as shown in Figure 5(a) point A. After that, the algorithm revert back the direction and the PV panel power is increased back again. At t=1.0s, the MPP is reached for solar irradiation of 1.0kW/m², but there is oscillation during the MPP state.

Figure 5(b) shows the simulation results of the proposed method. Figure 5(b) shows there is no oscillation after the MPP is reached at t=0.2s and t=0.9s. At t=0.716s, the solar irradiation is increased to 1.0kW/m², and then at t=0.75s, the proposed algorithm detects the increased in solar irradiation and responses correctly as shown in Figure 5(b) (Point C). The proposed method needs only 4 steps to
reach the MPP and the conventional method needs 6 steps. Hence, the proposed method is 0.1s faster than the conventional method during the increase in solar irradiation level.

![Figure 5. Simulation results: (a) Conventional Incremental Conductance (b) Proposed Incremental Conductance](image)

### 6. Conclusion
The proposed Incremental Conductance algorithm is used to track the MPP for the PV panel. From the simulation results, the proposed algorithm is able to track the MPP correctly and it is 0.1s faster compared to the conventional algorithm. Then, the proposed method does not show the steady state oscillation and is able to reduce the power losses. As a conclusion, the proposed method reacts faster and correctly against the change in solar irradiation level and it is able to eliminate the steady state oscillation.

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