Investigation on the Maximum Power Point in Solar Panel Characteristics Due to Irradiance Changes

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Abstract. One of the disadvantages of the photovoltaic module as compared to other renewable resources is the dynamic characteristics of solar irradiance due to inconsistency weather condition and surrounding temperature. Commonly, a photovoltaic power generation systems consist of an embedded control system to maximize the power generation due to the inconsistency in irradiance. In order to improve the simplicity of the power optimization control, this paper present the characteristic of Maximum Power Point with various irradiance levels for Maximum Power Point Tracking (MPPT). The technique requires a set of data from photovoltaic simulation model to be extrapolated as a standard relationship between irradiance and maximum power. The result shows that the relationship between irradiance and maximum power can be represented by a simplified quadratic equation. The first section in your paper

1. Introduction
Solar energy is one of the most important renewable energy sources. Solar energy is clean, inexhaustible and free compared to conventional non-renewable resources. It offers an option for clean (pollution free) energy source, with almost no running and maintenance cost. Besides, for remote systems such as radio communications, satellite earth stations, or at sites that are far away from a conventional power system, the hybrid systems have been considered as attractive and preferred alternative sources [1].

In the recent past years, PV power generation system has attracted more attention due to the energy crisis and environment pollution. One of the main renewable energy sources available in nature is the sun, usable for the direct production of electricity through photovoltaic (PV) systems [2]. However, Solar PV electricity output is also highly sensitive to shading and the crucial design involves the energy storage mechanism [3]. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output falls dramatically [4]. Besides, Photovoltaics has nonlinear internal characteristics. The voltage-power characteristics of the PV panel is varied which depends upon insolation and temperature. Considering the high initial installation cost of the PV system, it is always necessary to operate PV at its Maximum Power Point (MPP) [5]. Therefore, the dynamic condition of solar power characteristics due to some external factors such as solar irradiance and temperature requires the researchers to improve the charging control in order to optimise the solar power.
Tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system. As such, many MPP tracking (MPPT) methods have been developed and implemented. The methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware, popularity, and in other respects [6]. The conventional MPPT methods are generally categorized into the following groups according to the control strategies, that are 1) Perturbation and observation (P&O) methods, 2) Incremental conductance methods, 3) Constant current or constant voltage and 4) Miscellaneous (e.g., fuzzy control and voltage-based scheme among them P & O method has drawn much attention due to its simplicity. But the oscillation problem is unavoidable [7].

The traditional prediction of PV energy production is based on the classical approach of time series forecasting of solar energy and weather conditions, which are used to calculate the electrical energy of PV systems: Autoregressive models, Moving Average and Autoregressive Moving Averages are often used to model linear dynamic structures [2]. However, the investigation of the photovoltaic power characteristic in variance of irradiance met some challenges as the conventional MMPT methods rely solely on voltage, current and temperature. Therefore, the objective of this paper is to investigate the maximum power point tracking based on the actual irradiance level. Using a complete simulation model in Matlab Simulink, some sampling has been done to represent the model. Finally some characteristic equations has been proposed as the representation of a simple Power versus Irradiance linearized equation of the sampled model for the use of further research and implementation.

2. System Architecture
The overall block diagram of Solar Intelligent Control is shown in Figure 1 where it consists of the integration of three main subsystems which are MPPT Controller, Buck Converter and Power Monitoring.

![Figure 1: Block Diagram of Solar Intelligent Control](image)

2.1. Maximum Power Point Tracking (MPPT)
Maximum power point tracking (MPPT) is a technique used in solar systems to maximize the output power. Some parameters from solar panel are used as references to the power optimiser. In order to perform a more sustainable charging, the condition of the storage unit is taken into consideration to make sure the lifetime of the battery can be preserved.
Therefore, using simple linearization formula, the system evaluates four main variables that are Voltage, Current and Temperature to utilize the output current and voltage according to solar power characteristics.

2.2. *Buck Converter*

A buck converter is a step down DC-DC power converter which steps down the voltage rating while stepping up current from solar panel to the storage unit. The buck converter will make sure the solar panel draw power within specific value of voltage and current based on its highest power points.

2.3. *Power Monitoring*

A power monitoring subsystem is integrated into the Solar Intelligent Control to monitor the condition of solar panel and storage unit. The subsystem will monitor the degradation or defect on the solar panels and the State of Charge (SOC) of the storage unit.

3. *Result and Discussion*

3.1 *Photovoltaic Simulink Block Diagram*

The model of photovoltaic was constructed in Matlab/Simulink. A fundamental understanding about the behaviour of solar is achieved by using Simulink application in Matlab2014b as shown in Figure 2.

![Graphic](image_url)

*Figure 2: Solar Equivalent Simulink Model*
The characteristics of Power(W), Current(I), Voltage(V), and Irradiance(W/in\(^2\)); which is the flux of radiant energy per unit area normally measured in Watt per unit area of inch square. The parameters was analysed to propose the most suitable charger controller as the key to optimize the use of solar energy. The preliminary performance measurement are the voltage, current and power behaviour based on different value of solar irradiance. The irradiance value is the input value from the simulation diagram. Some sample irradiance values is taken into consideration starting from 0 W/in\(^2\), 100 W/in\(^2\), 200 W/in\(^2\), 300 W/in\(^2\), 400 W/in\(^2\), 500 W/in\(^2\), 600 W/in\(^2\), 700 W/in\(^2\), 800 W/in\(^2\), 900 W/in\(^2\), and 1000 W/in\(^2\).

Figure 3 shows the current and power relationship in solar panel. The model was simulated based on different value of irradiance ranging from 100 W/in\(^2\) to 1000 W/in\(^2\). Based on the graph, it is clear that the rated current increased when the irradiance level increases. The rated current for maximum irradiance is 8.5 A while the maximum power is 240 W.

Figure 4 shows the voltage and power relationship in solar panel. The model simulates behaviour based on different value of irradiance ranging from 100 W/in\(^2\) to 1000 W/in\(^2\). For 400W/in\(^2\), the optimum Voltage reference is 27.5V and the maximum output power is 65W while for 1000W/in\(^2\), the optimum Voltage reference is 29.5V and the maximum output power is 220W.
3.2 Linearizing the formula

In order to obtain the maximum power related to the Solar Irradiance, some sampling representing the highest possible power of the system is obtained as shown in Figure 5. Based on the power characteristics of solar panel, the relationship between Power and Irradiance has been simplified into a discrete samples to find out the standard relationship between Power and Irradiance for an optimised Maximum Power Point Tracking (MPPT) control. Using data cursor in Matlab, a tabulated data is performed in Table 1 for the use of linearization technique.

Considering the sets of data sampling, the linearized equations between Maximum Power and Irradiance is identified based on the standard equation stated in (1) and (2).

\[
P = mR + y \quad (1)
\]

\[
P = aR^2 + bR + c \quad (2)
\]

Where \( m, y, a, b \) and \( c \) are the coefficients of the equation, \( P \) is the maximum power, \( R \) is the Solar Irradiance. Using extrapolation technique, the equation (1) and (2) is plotted in Figure 6 to represent the relationship between maximum power and irradiance. The result shows that the quadratic equation and linear equation is in a very small proximity. Therefore to acquire more accurate control is better to use the quadratic equation while to prefer a simpler control it is better to use the linear equation.

![Figure 5. Maximum Power vs. Solar Irradiance](image)

![Figure 6: Equation for Maximum Power Point vs Irradiance](image)
Table 1: Maximum Power vs Irradiance

| Sample No. | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Irradiance, W/in$^2$ | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Maximum Power, W | 17.52 | 35.85 | 57.98 | 78.11 | 104.55 | 127.8 | 151.1 | 174.3 | 197.6 | 220.8 |

4. Conclusion
An extrapolation approach to investigate the relationship between maximum power point and irradiance level has been presented in this paper. By using a complete Photovoltaic Simulation model in Matlab Simulink, some sampling has been done according to various irradiance level in order to represent an optimized equation. Finally a quadratic equation has been proposed as the representation of a simple Power versus Irradiance. The result suggest the extrapolation technique is applicable to represent a simplified control of Maximum Power Point Tracking (MPPT) for the use of further research and implementation.

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