PV Hot Spot 탐지를 위한 부스트 컨버터 설계

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Photovoltaic Hot Spot Detection Method Integrated into a Boost Converter

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ABSTRACT

Solar energy has proven to be a potential clean energy source to help offset the large consumption of fossil. Nowadays, many research projects aim to enhance photovoltaic (PV) system performance and functionality. This research focuses on integrating self monitor capability into dc dc converters that control PV panels to detect a fault in series connected PV cells, called hot spotting. A detection method using ac parameter characterization is proposed and its operation is examined through simulation.

1. Introduction

Mismatch among cell electrical characteristics is the main cause of hot spotting, which leads to reverse bias, drastic cell temperature increase, accelerated cell degradation, and reduced panel power. Currently, the solution to mitigate hot spotting effects is a bypass diode or a recently developed active bypass switch over each substring in commercial PV panels. However, these two methods neither prevent hot spotting nor hot spot damage. Therefore, this research aims to implement a hot spot detection method using ac parameter characterization in a dc dc converter. According to experimental results, hot spotting in cells leads to an increase in both effective parallel resistance and capacitance when the PV string operates near the maximum power point (MPP). Using small signal analysis, parallel resistance can be measured using dc impedance and capacitance can be measured at a higher frequency of around 100 kHz.[1]

2. Hot Spot Detection Method

A full PV equivalent circuit model with reverse bias characteristics is shown if Fig. 1(a). It is modeled with associated resistance, capacitance, and inductance components, along with photocurrent source, forward and reverse bias diodes.

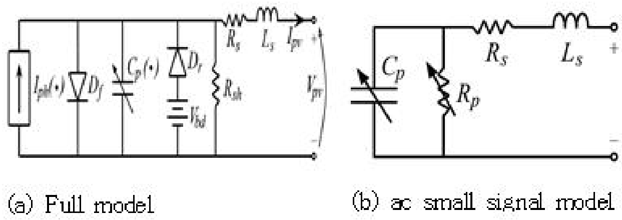

Fig. 1 Full (a) and ac small signal (b) PV equivalent circuit

For small signal analysis, dc components are ignored and the equivalent circuit only contains series resistance Rs, series inductance Ls, equivalent parallel resistance Rp, and equivalent parallel capacitance Cp, as shown in Fig. 1(b). Note that the values of Rs and Ls are assumed to be constant, but Cp and Rp model parameters vary depending on environmental conditions.

The PV impedance characteristics can be represented in Bode plot form, as shown in Fig. 2. Each component in the small signal circuit dominates at different frequencies. When there is change in the Rp value, it will cause the resistive magnitude region at low frequencies to move up or down directly with the change in resistance. Changes in Cp are visualized as the capacitive magnitude region at mid range frequencies shifting left for Cp increase and right for Cp decrease.[1]

In the next section, we will measure the dc impedance by a simulation in Matlab in order to detect hot spotting.

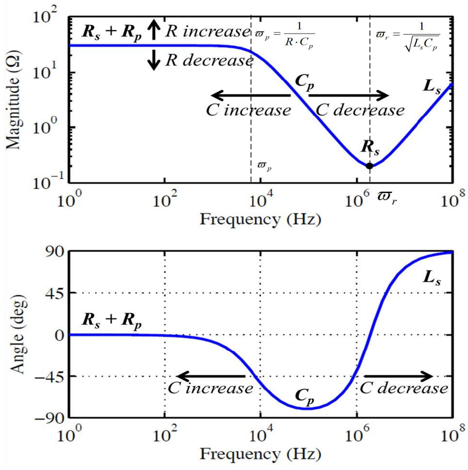

Fig. 2 Impedance Bode plot showing how the curve changes as R and C change

3. Simulation and results

A simulation was conducted in Matlab to implement the proposed dc impedance measurement for hot spot detection while operating the PV string at MPP (Fig. 3). In this simulation, a PV panel with 24 cells in series is connected to a boost converter running MPP tracking control. Dc impedance is obtained by utilizing the Perturb and Observe (P&O) algorithm inside the controller.

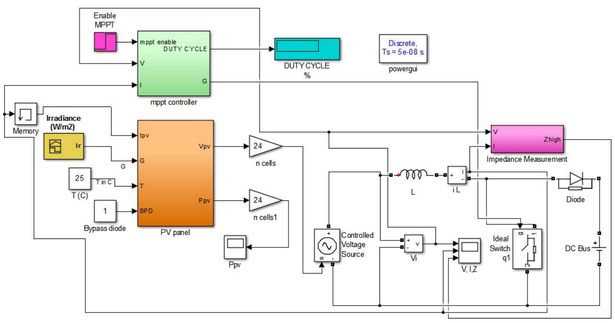

Fig. 3 The simulink block in Matlab containing 24 PV cells connected in series, a boost converter and MPPT controller.

The MPP tracking controller uses P&O to adjust the duty cycle D based on the change in output power P; the voltage V increment value is $\Delta D = 35 * 10^{-5}$. The dc impedance is calculated based on the difference between the present and previous values of the PV voltage and current used in the MPPT algorithm, according to the following equation. A detailed explanation of the algorithm is shown in Fig. 4.

$$Z_{dc} = -\frac{\Delta V}{\Delta I}$$

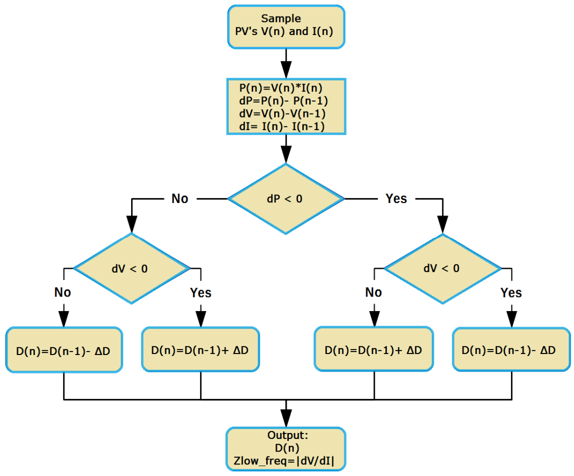

Fig. 4 P&O and dc impedance calculation procedure

A hot spotting condition was simulated with 1 cell shaded (200 W/m^2) and the other 23 cells unshaded (1000 W/m^2). First, 24 cells operated under full sun condition, then 1 cell was be partially shaded at t=0.02 s. As shown in Fig. 6, with no shading, the dc impedance is 1.65 Ω, and with one cell shaded, dc impedance increases noticeably to an average value of 10 Ω.

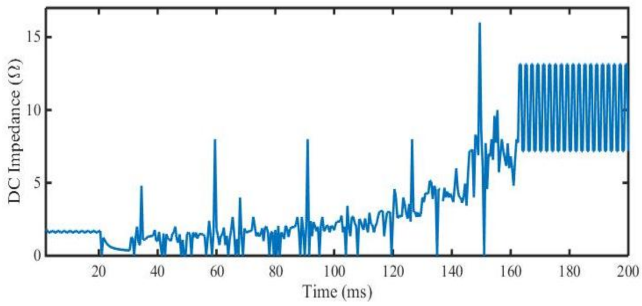

Fig. 5 Dc impedance measurement results

3. Conclusion

Based on a simulation in Matlab, it was shown that hot spotting leads to an increase in dc impedance, which can be used as part of a hot spotting detection method. Later, the capacitive region impedance will be measured using a boost converter at its switching frequency to determine whether the panel string is undergoing hot spotting based on the changing pattern of those two values.

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References

[1] K. A. Kim, G. S. Seo, B. H. Cho, P. T. Krein, "Photovoltaic Hot Spot Detection for Solar Panel Substrings Using AC Parameter Characterization," IEEE Trans. Power Electronics.