Recent Progress in the Development of Photovoltaic Module Mismatch Mitigation Techniques

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ABSTRACT: The failure of the bypass diode and partial shading are the most common causes of mismatch loss in photovoltaic (PV) systems. Therefore, as an alternative to the conventional bypass diode, several alternative mitigation techniques have been introduced to improve its drawbacks. This paper is to present the recent development of mitigation techniques due to hotspot and module mismatch. The standard test conditions (STC) parameters that are used in simulation including maximum power point (P_{mpp}), current at maximum power point (I_{mmp}), voltage at maximum power point (V_{mp}), short circuit current (I_{sc}) and open-circuit voltage (V_{oc}). Finding P_{mpp} is the amount of PV systems should produce and maintain if the voltage hasn't reached the V_{oc} value. The highest result of P_{mpp} among all techniques is 112.4W by using the current limiter technique.

Keywords: *Photovoltaic; Mismatch; Mitigation;*

1. INTRODUCTION

The photovoltaic (PV) device will play a critical role in supplying world energy for energy demand. Owing to different faults occurring both internally and externally in the system, PV systems suffer from a large amount of power loss. Faults are caused by a variety of factors, and these faults must be identified and removed as soon as possible if the faults are not eliminated throughout the system. System fault analysis is essential to increase reliability, extract maximum power and ensure the safety of the system.

2. METHODOLOGY

2.1 Mismatch conditions

Variations in PV production, impure materials, aging of PV units, and soldering are definite causes of internal mismatching. This could reduce the output power by approximately 10% which is identified as a permanent issue in PV units [1]. On the other hand, mismatching causes such as shading, power converters, and diode bypassing power losses are identified as external in PV units. Taking into count the PV unit glass does lead to degrading the glass conduction which also results in reducing the output power of the PV unit. Dust, on the other hand, degrades the power with an approximate average of 6.2, 11.8, and 18.7% for an exposure duration of one day, one week, and one month, respectively [2].

Figure 1 shows the classification of mismatch faults in which they are identified as temporary and permanent types. Cell parameters have an impact on the shading effect on a particular cell. For example, the parallel or series impedance that has a relation to the rate of inverse current. Yet, the mismatch error heats the PV cells or units which may result in reaching a massive temperature and hence permanently damage the PV unit. The temporary mismatch errors make an approximation of 3-10% power losses. The efficiency of the whole system along with the lifetime duration of PV units are affected by these errors [3].

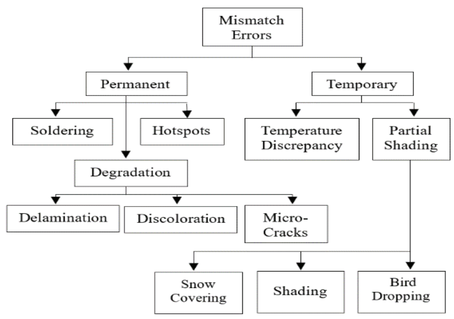

Figure 1 Classification of mismatch conditions

2.2 Mismatch mitigation techniques

This paper focuses only on four different mismatch mitigation techniques that have been published recently.

2.2.1 Bypass diodes technique

Figure 2 shows a circuit diagram contains equivalent SMs with bypass D_1 and D_2. The connection of bypass diode in a PV unit is made in parallel to minimize the impact of mismatching by restraining the reverse voltage. The parallel connection is made across each SM. These diodes are mainly proposed to protect the shadowed cells from any temperature rise [4].

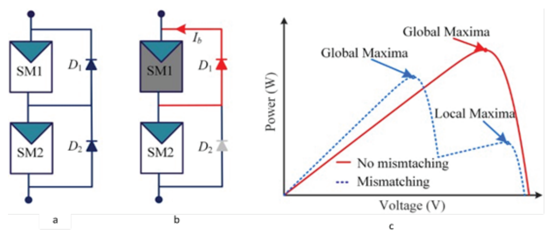

Figure 2 PV SM1 and SM2 with parallel bypass diode D_1 and D_2. (a) the circuit diagram, (b) current flow as shaded occurred, and (c) P–V characteristic curve [4].

2.2.2 *BJT-based bypass technique*

Figure 3 shows the technique of implementing the BJT as a bypass element to replace the bypass diodes. The BJT voltage drop at the saturation region is usually quite low [5]. Therefore, it improves the total output power through a reduction in the bypass power losses that can be extracted using the following expression

$$P_L = V_{CE} I_b \tag{1}$$

where I_b denotes BJT transistor current and the collector-emitter V_{CE} is the voltage drop. The effectiveness of this method is that it makes use of the generated reverse voltage during shading conditions to provide bypassing. Therefore, this method contributes to extending the lifetime of SM which in turn extends the lifetime of all PV units.

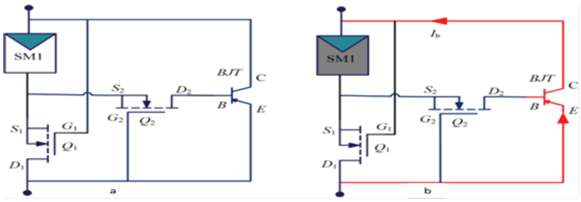

Figure 3 BJT-based bypass technique. Schematic diagram during normal and during shading occurs [5].

2.2.3 *Series MOSFET bypass Method*

Figure 4 shows that there's a power MOSFET Q_1 connected in series with SM1 which is the structure of the MOSFET bypass method. Implementing this bypass method will lead to a decrement in the shaded PV cell's temperature, which in turn makes the SM and the entire PV unit more reliable. The vital role of this method is that it minimizes the hot spot temperature and lessens the loss of power during shading. However, if we are to compare with the bypassing method using Si and Schottky diodes, this method makes more power losses.

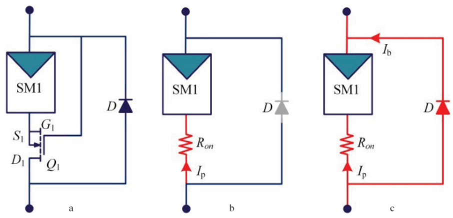

Figure 4 Series-MOSFET-based bypass technique (a). Schematic diagram, (b) Bypass diode OFF state, (c) SM is shaded [6]

2.2.4 *Current Limiter Mitigation Method*

The circuit is not only providing a suitable solution to mitigate the problem of the hotspot, but also eliminating the increase of the PV cells' temperature during partial shading scenarios. However, the current limiter circuit has a limitation in which there is a large voltage drop in the operation of the current limiter, hence, the PV module voltage at the output of the limiter would be affected and less power would be produced [7].

2.2.5 *Methods Comparison*

The PV module which is having the bypass diode technique produces P_{pmp} equal to 102W during one of the submodules is subjected to 20% shading. While the BJT-based bypass technique produces P_{pmp} is 60.74W. Otherwise, the MOSFET bypass technique produces 80.25W. On the other hand, the current limiter mitigation technique result shows better than other techniques by producing P_{pmp} up to 112.4 W when subjected to the same shading percentage. These configurations are shown that using the current limiter mitigation technique provides an output power increment of 9.25% as compared to the bypass diode technique, 46% as compared to the BJT-based bypass technique and 28.6% compared to the MOSFET bypass method.

3. CONCLUSION

A brief discussion of mismatch mitigation methods for PV units was presented. Several categories of mismatch effects, which could be practically occurred. Various passive and active methods have also been overviewed. It is seen that the current limiter technology can be considered as an effective method to reduce the hotspot effect and improve the PV output power.

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