Extraction of maximum power from SPV Arrays (SPVA)

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ABSTRACT

Considering the high initial capital cost of a Solar Photovoltaic (SPV) source and its low energy conversion efficiency, it is essential to operate the SPV source at Maximum Power Point (MPP) so that maximum power can be extracted. Techniques to extract maximum power from SPV Arrays (SPVA) where some of the cells are not receiving the full insolation (partial shaded condition) has been presented in this paper. Effects of reconfiguration of the array and tracking of load have been analyzed for maximum power availability.

Key words- Solar Photovoltaic, Maximum Power Point,

1. INTRODUCTION

The main objective of this paper is to present research work on the design and development of a novel PV fault detection and degradation analysis. PV fault detection algorithms have been widely used to detect various faults occurring in PV installations. These algorithms relay on several parameters of PV installations such as voltage, current, power, and the series resistance of PV modules and depend on some environmental factors such as ambient temperature, and solar irradiance. However, the listed parameters are not always available in PV sites; thus, it is required to improve the existing PV detection algorithms in order to detect PV faults using fewer PV and environmental parameters [1]. However, the measured data were analyzed using laboratory-based experiments, which did not contain a real-time long-term data measurement from installed PV modules in various locations. Firstly this paper will describe the development of various PV fault detection algorithms which are divided into three main categories: mathematical and statistical analysis algorithms, Fuzzy Logic PV fault detection systems, and ANN based systems. All these algorithms depend only on the power and voltage ratios of the PV installations. The second contribution of this work is the design of the novel PV hot spot mitigation techniques [2].

1.1 ACTIVE POWER FILTERS (APF) PHOTOVOLTAIC ENERGY SYSTEM

The output of solar PV cell is a Direct Current (DC), where the current is determined by the area of the cell and amount of exposed solar irradiation. The voltage of the individual silicon cell is in the order of 0.5V. Thereby, the cell has to be connected in a series to constitute modules with reasonable voltage level.. PV systems are usually used in three main fields: 1. Satellite applications, where the solar arrays provide power to satellites, 2. Off-grid applications, where solar arrays are used to power remote loads that are not connected to the electric grid, and 3. On-grid, or grid connected applications, in which solar arrays are used to supply energy to local loads as well as to the electric grid. The basic element of the solar PV power conditioning system is the DC-DC converter. If the purpose is to charge a battery or regulate a DC- bus as in space and telecom applications, the system can be implemented by using only the DC-DC converter as depicted in Figure 1.

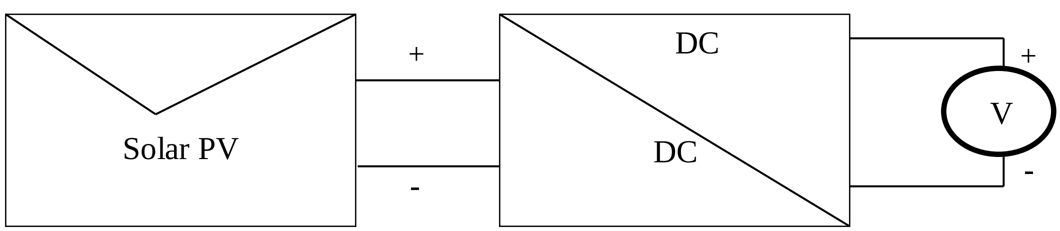


Figure 1: Basic element of power conditioning system

The efficiency of solar PV system used in space satellite mainly depends on the efficiency of DC-DC power conditioning process. High efficient DC-DC converter has to be designed which is more suitable in solar PV application. Unfortunately, the performance of solar PV system is affected due to non-linear dynamics in DC-DC converter used in MPPT system, and leads to undesirable operation in solar PV system. Also DC-DC converter used in solar PV system should be stable and the input voltage is kept within the specified range under disturbances at the source voltage and the change in irradiation. With above motivation, the PV powered DC-DC Cuk converter-based MPPT system is considered in this research. The objectives of the research work are stated as follows:

- The development of fault detection method for PV modules defective bypass diodes is presented.
- Bypass diodes are nowadays used in PV modules in order to enhance the output power production during partial shading conditions. However, there is lack of scientific research which demonstrates the detection of defective bypass diodes in PV systems.
- This paper propose a PV bypass diode fault detection classification based on fuzzy logic system, which depends on the analysis of Vdrop, Voc , and Isc obtained from the I-V curve of the examined PV module.

H. H. Khaing et al. [1], employed variable step size incremental conductance maximum power point tracking technique in photovoltaic systems to make full utilization of PV array output power which automatically adjusts the step size to track the PV array maximum power point. Y. Zhao et al. [9], proposed a technique for demonstrating and reproduction of photovoltaic clusters. M. Z. S. El-Dein et al. [10], the got results demonstrate that the traditional buck and support converters are not fit for recreating the entire I–V bend of PV generators. Y. Zhao et al. [11], developed a modeling and controller design of the PV charger system implemented with the SEPIC converter. Y. Zhao et al. [12] analyzed the bifurcations in current controlled Luo topology, operating in continuous conduction mode using continuous-time model.

2. PROBLEM FORMULATION

There are different types of solar PV cells. However, the most common and commercially available types are the mono crystalline, polycrystalline and amorphous cells. The conversion efficiencies of the solar cells manufactured by the various technologies are given below (PV Magazine 2011):

1. Mono crystalline – 13% to 25%
2. Polycrystalline – 10% to 20%
3. Amorphous cells – 6% to 13%

Silicon PV cells typically produce only about 0.5 V and hence a number of cells need to be connected in a series, in order to get the required voltage level. A PV string is formed by arranging a number of PV modules in series. A PV array is a collection of PV strings. A group of PV cells connected together is called PV module. The number of modules in each string is specified according to the required voltage level of the array. The number of strings in each array is specified according to the required current rating of the array. Most PV arrays have a power diode, called the bypass diode, connected in parallel with each individual module or a number of modules.

The function of this diode is to conduct the current when one or more of these modules are damaged or shaded. Another diode, called the blocking diode, is usually connected in series with each string, to prevent the reverse current flow and protect the modules. Figure 2 shows the PV array configuration.

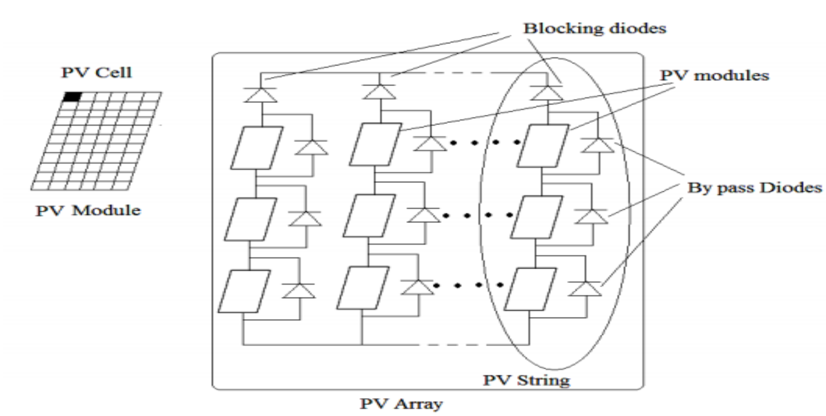


Figure 2: PV Array configurations

The P-V and I-V characteristic curves of the PV module under different values of solar irradiation and temperature are shown in Figures 3.

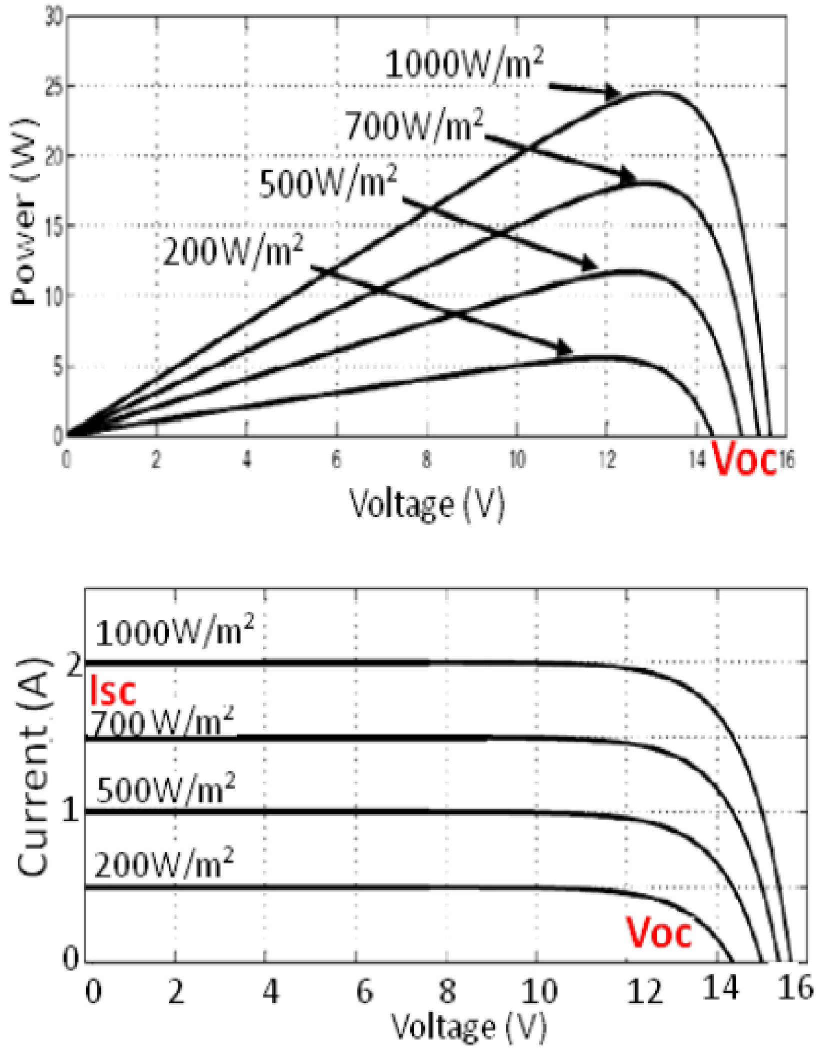


Figure 3: The P-V and I-V characteristics curve at different irradiation levels and a constant temperature (250C) condition

The electric characteristics of the PV cell depend mainly on the irradiance received by the cell, and the cell temperature. Figure 4 displays the electrical characteristics of the cell at different levels of irradiance and a constant temperature. It is clear that the change in irradiance has a strong effect on the short circuit current (I_{sc}) and output power of the cell, but negligible effect on the open-circuit voltage (V_{oc}).

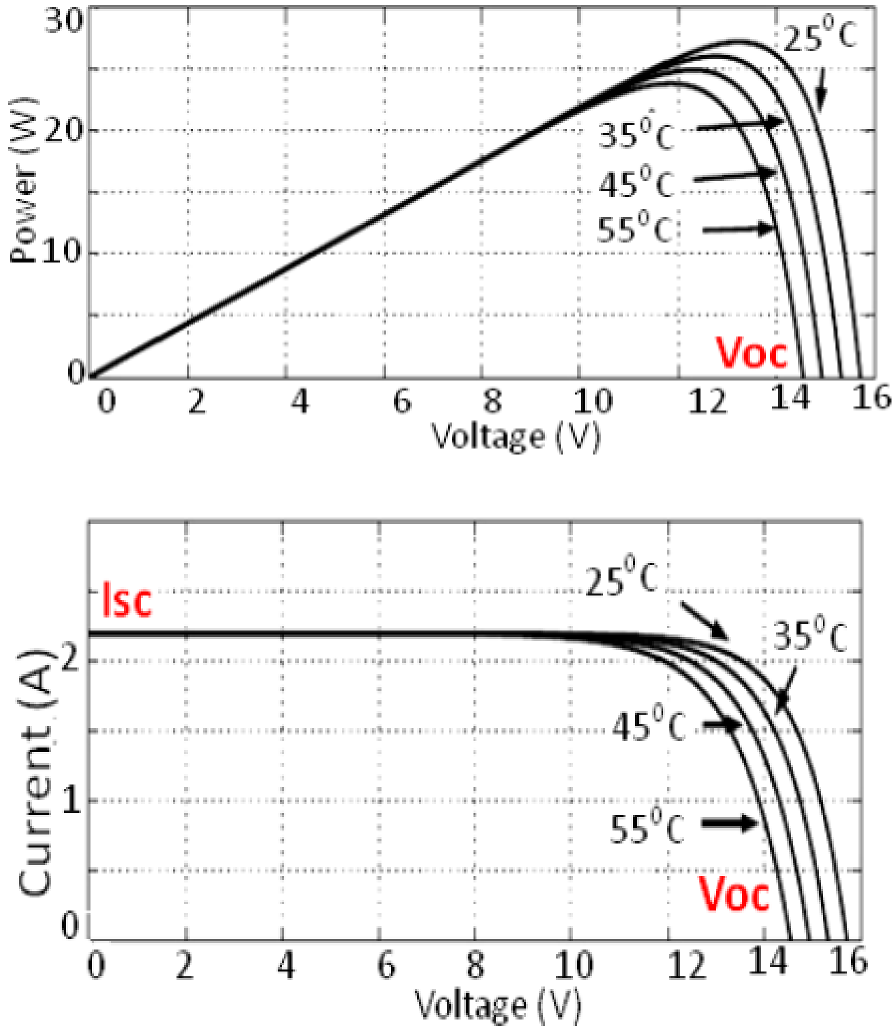


Figure 4: The P-V and I-V characteristics curve at different temperature levels and a constant irradiation (1000 W/m2) condition

3. Methodology

A support converter (stride up converter) is a DC-to-DC power converter with a yield voltage more prominent than its data voltage. It is a class of exchanged mode control supply (SMPS) containing no less than two semiconductors (a diode and a transistor) and no less than one vitality stockpiling component, a capacitor, inductor, or the two in blend. Channels made of capacitors (now and then in mix with inductors) are regularly added to the yield of the converter to decrease yield voltage swell. A support converter (stride up converter) is a DC-to-DC power converter with a yield voltage more prominent than its info voltage. It is a class of exchanged mode control supply (SMPS) containing no less than two semiconductors (a diode and a transistor) and no less than one vitality stockpiling component, a capacitor, inductor, or the two in blend. Channels made of capacitors (now and then in mix with inductors) are regularly added to the yield of the converter to decrease yield voltage swell.

The diode blocks the flow of current and so the load current remains constant which is being supplied due to the discharging of the capacitor. The model is shown in Figure 5.

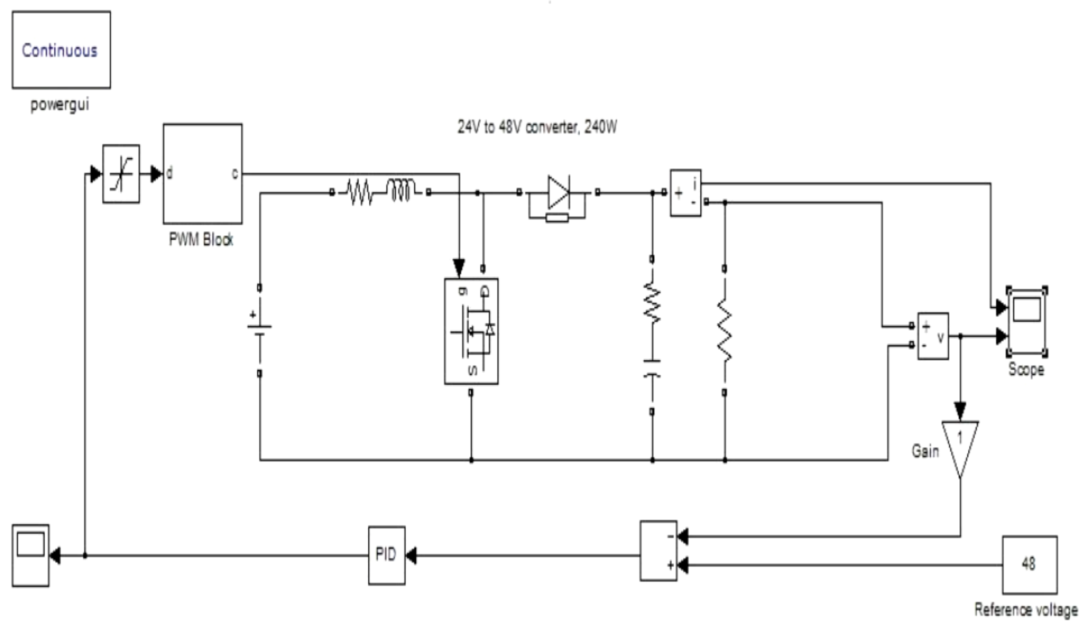


Figure 5: Simulation Model of Closed Loop Boost Converter

The switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation.

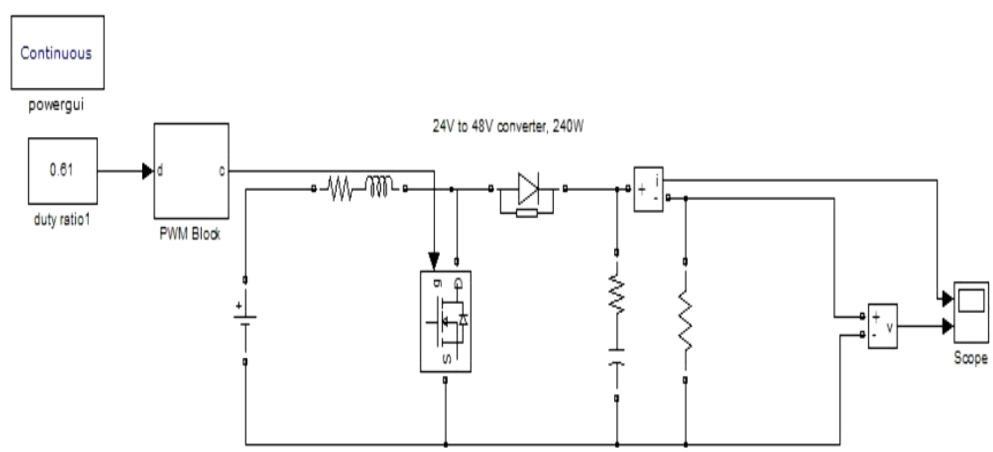
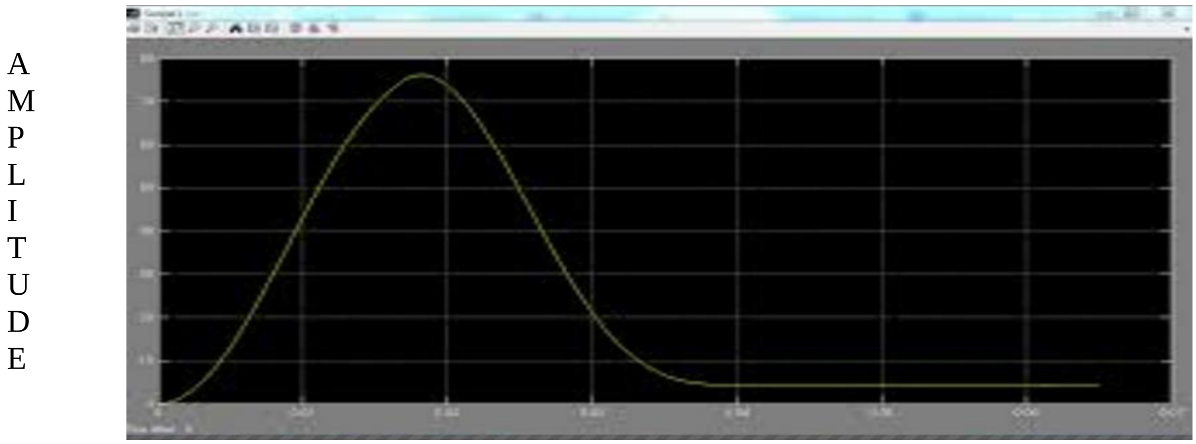


Figure 6: Simulation Model of Open Loop Boost Converter

4. Results and Analysis

In figures 7 to 8, the most fundamental limitation on the maximum output voltage for the boost is the maximum rated voltage of the MOSFET and/or diode. This is specified in the data sheet and is one of the first steps in choosing a candidate converter for a given application. A more practical limitation arises from the maximum duty ratio at which the converter can operate. The duty ratio is defined as the on-time of the MOSFET divided by the total switching period. In all DC/DC converters the output voltage will be some function of this duty ratio.



Voltage

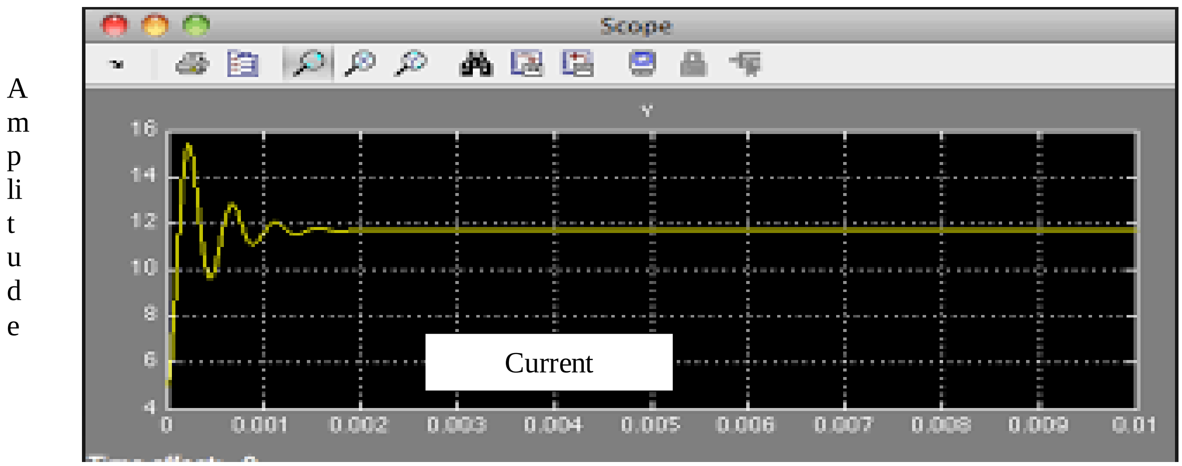


Figure 7: Open Loop Control Characteristics of Boost Converter

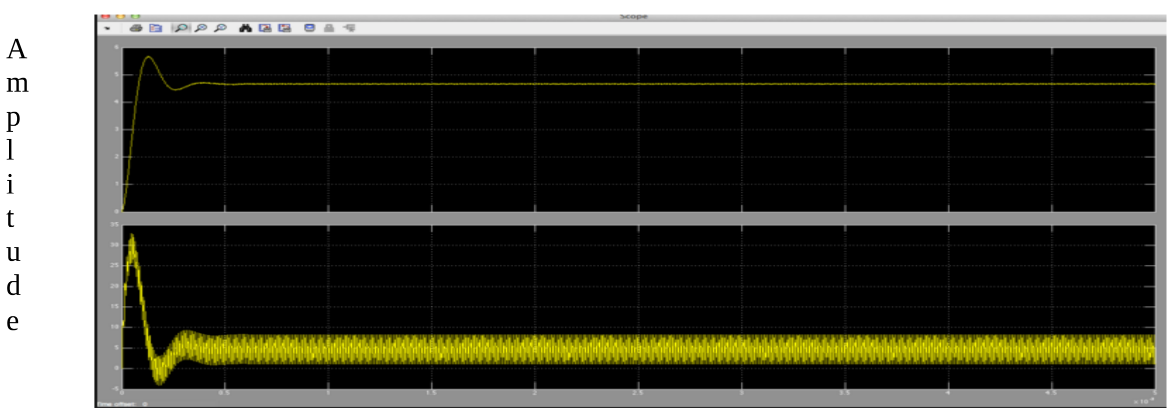


Figure 8: Closed loop control characteristics of Boost Converter

The voltage generated by a single solar cell is very low, around 0.5V. So, a number of solar cells are connected in both series and parallel connections to achieve the desired output. In case of partial shading, diodes may be needed to avoid reverse current in the array. Good ventilation behind the solar panels are provided to avoid the possibility of less efficiency at high temperatures.

5. Conclusion

This paper proposed a fault detection method for PV module defective bypass diodes. The detection method is based on Mamdani fuzzy logic system, which depends on the analysis of Vdrop, Voc, and Isc obtained from the I-V curve of the examined PV module. The fuzzy logic system depends on three inputs, namely percentage of voltage drop (PVD), Percentage of open circuit voltage (POCV), and the percentage of short circuit current (PSCC). The proposed fuzzy system can detect up to 13 different faults associated with defective and non-defective bypass diodes.

The detection system achieved high detection accuracy during the validation process. In addition, the fuzzy system was evaluated using two different PV modules installed at the University of Huddersfield. Finally, in order to investigate the variations of the PV module temperature during defective bypass diodes and partial shading conditions.

REFERENCES

[1] H. H. Khaing, Y. J. Liang, N. N. M. Htay, and J. Fan. “Characteristics of different solar PV modules under partial shading,” Int. J. Elect., Computer, Energetic, Electron. Commun. Eng., vol. 8, no. 9, pp. 1411–1415, 2014.

[2] Y. Zhao, J. F. de Palma, J. Mosesian, R. Lyons and B. Lehman, “Line– line fault analysis and protection challenges in solar photovoltaic arrays,” IEEE Trans. Ind. Electron., vol. 60, no. 9, pp. 3784–3795, Sep. 2013.

[3] M. Z. S. El-Dein, M. Kazerani, and M. M. A. Salama, “Optimal photovoltaic array reconfiguration to reduce partial shading losses,” IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 145–153, Jan. 2013.

[4] Y. Zhao, B. Lehman, R. Ball, J. Mosessian, and J. de Palma, “Outlier detection rules for fault detection in solar photovoltaic arrays,” in Proc. 28th Annu. IEEE Appl. Power. Electron. Conf. Expo, Long Beach, CA, USA, Mar. 17–21, 2013, pp. 2913–2920.

[5] Y. Zhao et al., “Decision tree-based fault detection and classification in solar photovoltaic arrays,” in Proc. 27th Annu. IEEE Appl. Power Electron. Conf. Expo., Orlando, FL, USA, Feb. 5–9, 2012, pp. 93–99.

[6] Z. Li, Y.Wang, D. Zhou, and C.Wu, “An intelligent method for fault diagnosis in photovoltaic array,” in Proc. Int. Conf. Syst. Simul. Sci. Computer., 2012, pp. 10–16.