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A Hybrid Model of Grid Connected Sola Photovoltaic (PV) Cell with Partial Shading

Deven Bhardwaj* and Akhil Gupta

Department of Electrical Engineering, Chandigarh University, Mohali - 140413, Punjab, India;
bhardwajdeven99@gmail.com, akhilgupta1977@gmail.com

Abstract

SolarPhotovoltaic (PV)-Hydro Diesel cells are being used in electric power sector from a very long time. These solar PV cells have found their wide utilisation in commercial aspects. With the reduction of oil based fossil fuel resources, the various advancements taking place in solar PV technology have further amounted to this important cause. A major challenge in this field is to track the point of highest output power from the solar PV cells. In order to achieve this, various Maximum Power Point Tracking (MPPT) techniques have been studied and analysed in the literature. Out of all, the two techniques Perturb and Observe (P&O) and Incremental Conductance (IC) are the basic MPPT techniques which are simple to implement and analyse. This paper endeavours a novel adaptive new hybrid technique algorithm which is based on inference system for MPPT technique. The proposed hybrid under partial shading solar PV model with MPPT technique performs quite better when compared with other techniques in terms of transient state response.

Keywords: Double-diode,Maximum Power, Perturb and Observe, Photovoltaic, Single-diode

1. Introduction

Today, in India, the major share of electric power is harnessed from the coal based or non-renewable energy source. It will continue to be a major source of pollution and other environmental degradation. Finding the sustainable alternative is becoming increasingly urgent due to these problems and the dwindling supply of coal based resources. After hydro and wind type of electric power, Solar Photovoltaic (PV) is third most important renewable energy sources in terms of globally installed capacity. In Solar PV system, solar panels are used for converting solar energy into electrical energy. These solar panels consist of PV cells (also sometimes called as solar cells).

The lack of adequate transmission capacity is one of major impediment in implementing renewable energy sources into transmission utility grid[1]. It also presented a novel control for a grid-connected solar PV farm which can improve transient-state stability limit. It also improved power transfer capability of transmission line into utility grid. An algorithm for a new MPPT technique, which can effectively, improves the performance of a solar PV system[2]. The proposed algorithm has been explained in two sections, one is set-point calculation whereas another is fine-tuning. The calculation of set-point is based on method of short-circuit current, in which approximation of maximum power is done. In second section, an exact amount of maximum solar PV power is tracked by fine-tuning. This process is based on basic Perturbation & Observation (P&O) MPPT technique. In [3] it is suggested that MPPT techniques of analog nature, which provides faster response over MPPT techniques of digital type. Due to the fact that bandwidth of the analog type loop is higher, thus, most analog MPPT techniques require analog type multipliers. These multipliers are expensive in cost and consume more power. Hence, different low-cost microcontrollers which consume low-power, with built-in hardware digital multipliers have been manufactured by Texas Instruments and Microchip. In [4] a voltage-based and current-based MPPT technique is presented and discussed. It has been found that both approaches are efficient and simple. These MPPT approaches present poor active power tracking efficiencies particularly at variable insulation levels. In [5] a new methodology is introduced. The analysis and derivation of the non-linear *I–V* curves of

*Author for correspondence

a solar PV module are completed by explaining a natural type logarithmic-index. It has been found that it improved tracking speed over conventional MPPT methods likewise hill-climbing method. The utilized logarithmic-index index is complicated for real time calculations particularly with an 8-bit and 16-bit microcontroller chip.

In [6] it is discussed that 50 W solar PV array simulation, which is based on two-diode model. To reduce the computational time, the input parameters are reduced as the values of series and parallel resistance are estimated by iteration method. The results obtained through simulation have been compared with the datasheets of the manufacturer for the final validation. In [7] it is discussed that the 36 W PV array simulation, which is based on one diode model with unique step-by-step procedure for the simulation of PV module. It has been found that the mathematical modelling procedure helps in the closer understanding of Current-Voltage (*I-V)* and Power-Voltage (*P-V)* characteristics of PV module. In [7], it is discussed that the simulation modelling of single-diode, is based on solar radiation and variable temperature of the system. The results obtained through the simulation have been compared with the data sheets of the manufacturer for final validation. It has been found that the simulation waveforms are in conformity with the waveforms obtained through the manufacturer data sheets. In [8]it is discussed that the 120 W PV array simulations based on the two-diode model. These models are implemented in the Mat lab through programming using a flowchart. The results obtained through simulation have been compared with the datasheets of the manufacturer for the final validation. It has been found that the simulation waveforms are in conformity with the waveforms obtained through the manufacturer data sheets.

This paper presents a comparative analysis of single-diode and double-diode solar PV model. In addition, the impact of partial shading on the performance of solar PV array is also highlighted. This study also aims at presenting the output of DC-DC boost converter under single-diode and double-diode solar PV model. The simulation results confirm the validation when compared with the manufacturer data sheets.

2. Solar PV Array Modelling and Analysis

The PV cell is similar to a PN junction diode which is made up of p-n junction semiconductor material and exhibits the PV effect by virtue of which solar energy is converted into direct current electrical energy. The PV effect is a phenomenon in which electrons are jumped into a higher level of energy band by incident light due to which these electrons act as a charge carrier for the flow of current. The charge carriers are electron-hole pairs in a solid semiconducting material.

The PV cells are devices, which absorb the daylight and convert it into the electrical power using photovoltaic effect. These solar PV cells can further be modified by changing the chemical properties so that efficiency level can be enhanced. From the literature survey, it has been found that the silicon element used in PV cell is pure, however, poor conductor of electric current. This element contains four electrons in its valence shell, which function in the form of tetrahedral crystal lattices. Nowadays, the consumption of electric energy using solar PV cells is increasing, besides exploring the potential of any renewable energy source. However, due to availability of limited electric power resources, these sources have been projected as the source of future energy. In this direction, significant developments have been made since last two decades in research and development of renewable systems particularly, harnessing and controlling methods of wind-power, and solar energy. The electric power generated from solar PV technology is eco-friendly and pollution free. It is thus, regarded as most environmental friendly and reliable source of electric energy. Additionally, the solar PV electric energy system has high cost and low electric energy conversion efficiency. To overcome these quality issues, maximum solar PV electric power is extracted from a solar PV panel using the Maximum Power Point Tracking (MPPT) methods. These methods optimize the conversion efficiency of overall solar PV generation systems. Recently, the solar PV technology has been made more attractive as it integrates various merits: low maintenance, environmental pollution free friendliness and complete absence of variable as well as fixed fuel cost. But, the overall electrical conversion efficiency of a solar PV generation system is less. It is due to the fact that a solar PV cell depicts non-linear voltage-current and voltage-power characteristics. Furthermore, both non-linear characteristics depend on changing environmental conditions such as ambient PV panel temperature and variable solar radiation. In order to remove this non-linear nature, MPPT tracking algorithms are used for efficient operation which quickly derive maximum active power from solar PV arrays.

The major function of MPPT is to extract the maximum available real power from PV module at

maximum power point by making them to operate at most efficient voltage. This point on the power voltage curve is called the Maximum Power Point (MPP). Thus, the MPPT technique evaluates the output voltage of solar PV module, which is compared with battery voltage. The optimum power is fixed which a solar PV module or array is able to produce for charging battery. It then converts it to maximum voltage, which enables to draw maximum current from battery. Power can also be supplied to connected DC load, that is further directly connected to battery. This is called the modified form of single-diode circuit, which takes into account effect of recombination by introducing another p-n junction diode in parallel. However, there are two diode-quality factors, which have been unknown and make the total number of equations with unknown parameters. With lower values of solar radiation and ambient temperatures, the proposed two-diode model produces accurate power-voltage curve on comparing with single-diode solar PV model. The output voltage and current relation in a double-diode solar PV cell is given by Equation 1.

$$V_a = \frac{akT_c}{q}\ln\left(\frac{I_{ph}+I_{rs}-I_a}{I_{rs}}\right) - R_s I_a \text{ , and}$$

$$I_a = I_{ph}N_p - I_{rs}N_p e^{\left\{\left(\frac{q}{akT_c\left(\frac{V_a}{N_s}+\frac{I_a R_s}{N_p}\right)}-1\right)\right\}} - \frac{N_p}{R_p}\left(\frac{V_a}{N_s}+\frac{I_a R_s}{N_p}\right) \quad (1)$$

where, $$I_{ph} = [I_{sc} + K_i(T_c - T_x)\frac{S_c}{S_x}]$$

The solar PV modules are connected in series and parallel, which forms a solar PV array. It matches the active power requirements of connected load with required output voltage and output current. The total active output power in solar PV array is always less than sum of rated maximum power of each individual solar PV module. One of the major reasons of this is called the partial shading. When solar PV modules are serially connected, the overall performance is affected adversely when solar PV cells are not uniformly illuminated. The solar PV cells connected serially are forced to carry the equal current whereas, few solar PV cells under the influence of shading produce less output current. The shaded solar PV cells get reverse biased then acting as loads for the system, thus, the unshaded PV module drains active power from fully illuminated solar PV cells. The hot-spot problem arises which leads to irreversibly damage to the system, if the system is not appropriately protected.

3. Control Formulation Adopted for Solar PV Modelling

From the above literature survey conducted, it has been found that the output of solar PV array depends on variable solar radiation and variable atmospheric temperature. In the whole discussion, no discussion has been presented which can highlight the impact of partial shading on performance of solar PV array. The partial shading causes the formation of local hot spots and causes the increase in temperature of PV array. Also, it has been found that there is sufficient difference between the performance of single diode and double-diode model. Therefore, the simulation of PV array including the partial shading has been proposed. In addition, the comparative analysis of single-diode and double-diode solar PV model has been done in this present work.

The paper proposes a novel strategy to implement multi junction solar cell and simulate it for varying temperature and irradiance conditions. The model will also be developed for partial shading conditions and the performance will be enhanced by applying a novel MPPT technique. The performance will be compared for single-diode and double-diode model. The design has been developed on Simulink toolbox of Mat lab, whereas the algorithm codes have been written in editor of Mat lab. The Neural Network (NN) control has been designed using NN-toolbox of Mat lab software[9]. First of all, using double-diode model solar PV cell is designed by combining characteristics of solar PV cell. During simulation, each individual element of the solar PV cell is modelled as a separate subsystem as depicted through Figures 1, 2.

4. Simulation Results and Discussion

This section presents the various results obtained for the model discussed in the previous sections. Voltage output of the cell at the end of the converter. As shown in Figures 3, 4 the voltage first rises and then becomes steady at a constant value. The reduction in transients in the starting is attributed to the double-diode model and MPPT. The model is also simulated for the same initial conditions without application of MPPT. The results are shown, when the PV is partially shaded and MPPT is not applied, Figures 5, 6.

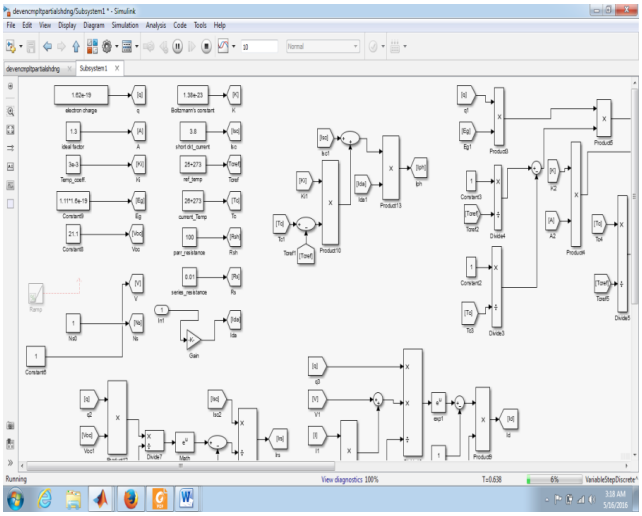

Figure 1. Modelling of the solar PV cells.

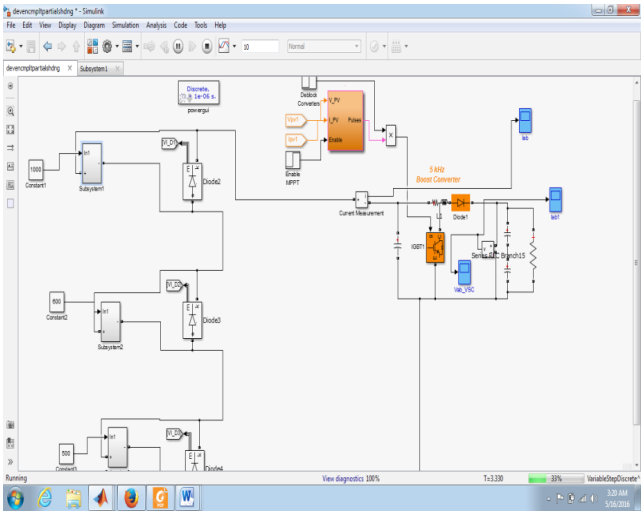

Figure 2. Simulink model of overall proposed model.

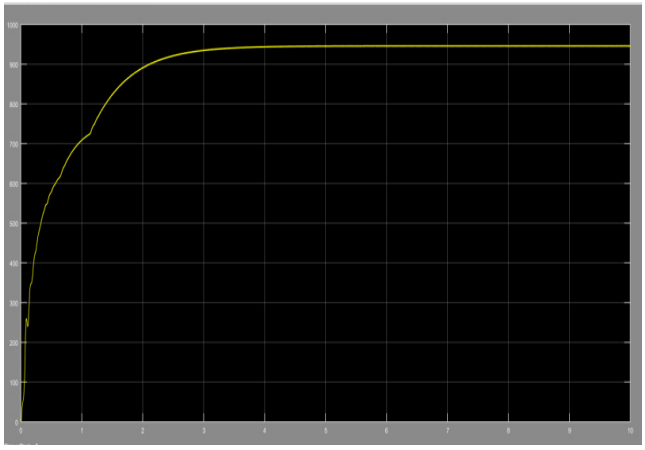

Figure 3. Output voltage of solar PV cell.

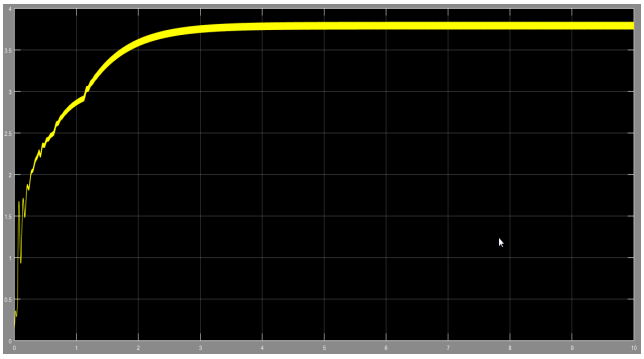

Figure 4. Output current of Boost Converter.

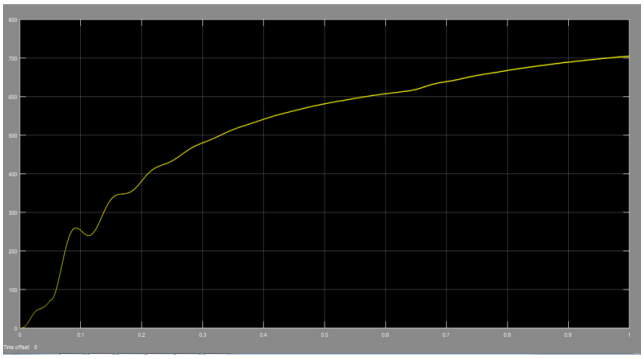

Figure 5. Output voltage of solar PV cell using double-diode model.

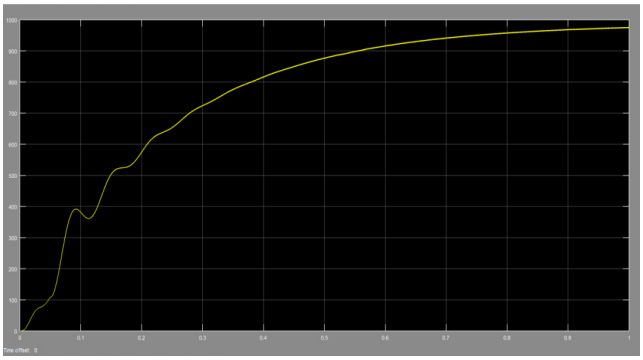

Figure 6. Effect of partial shading on the solar PV cell.

As it can be observed, that the net voltage decreases when MPPT is not applied. Also the model is simulated for normal conditions of 1000 W b /m^2. As observed, the partial shading. In condition decreases the net output voltage. When partial shading is removed the output is higher which is expected. A two-diode model is also simulated for the same conditions and the results are given below. The impact of partial shading on the double-diode model is depicted in Figures 7–9.

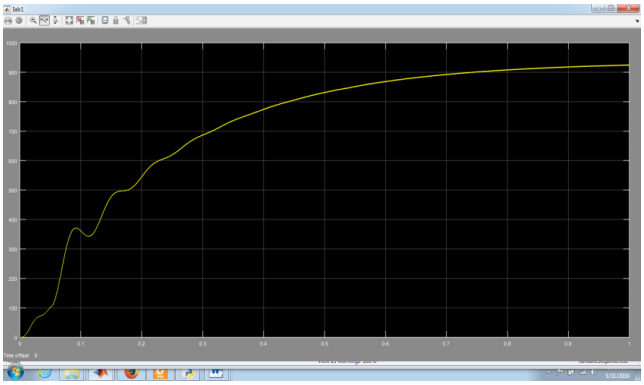

Figure 7. Effect of partial shading on the double-diode model.

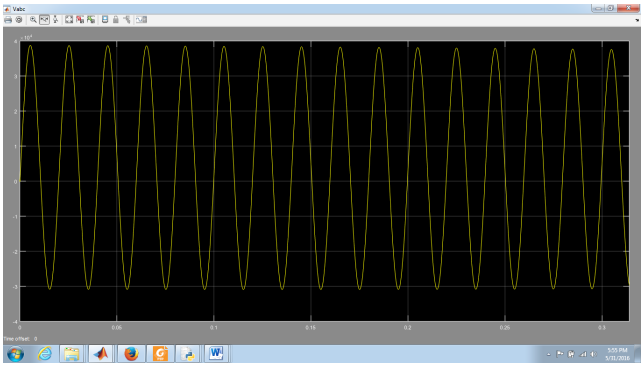

Figure 8. Impact of partial shading on the output voltage.

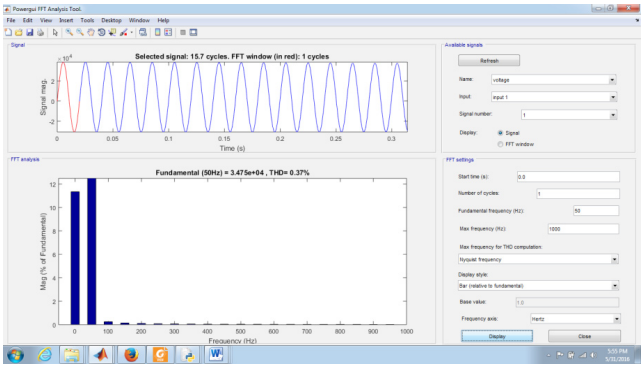

Figure 9. Total harmonic distortion analysis.

5. Conclusion

The paper attempted to implement a double-diode multi-junction solar cell for improved performance with consideration of partial shading factor. Solar PV cells have become very important area of research in recent years and have drawn the interest of the researchers all around the world. Solar PV cells depend on the type of cell used and recently multi-junction cells with double-diode are preferred. The result of developed hybrid model was found to be superior over incremental conductance MPPT technique in terms of magnitude of output voltage and its harmonic content. It has been observed that the harmonic content reduces using our proposed approach. Also, on doing the comparative analysis of currents, the transient and unwanted oscillations die out fastly in hybrid model, whereas in incremental conductance MPPT approach the oscillations are sustained. The model can be utilized for connection to grid in partial shading conditions and meta-heuristic approaches can be tested for the same.

6. References

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