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Impact of Shading on the Output Power of Photovoltaic Array

Mohiuddin[1], Mr. Saif Ahmad[2] Mohd Tahseen[3]
Dept. of Electronics & Communication Engineering Integral University, Lucknow (U.P), India
Corresponding Author: Mohiuddin

Abstract: The photovoltaic systems are to make it energy efficient. Partial shading reduces the energy yield of photovoltaic systems and introduces multiple peaks in the P-V characteristics. The maximum power point trackers work in conjunction with the boost converter and track the global peak in the P-V characteristics. The boost converter used for maximum power point trackers is generally designed to operate with high efficiency at the maximum power point voltage of the array by assuming a single peak power point on the P-V characteristics. However, the efficiency of the boost converter varies with the input voltage, and the maximum power point of the load when the converter efficiency is considered is different from the maximum power point of the photovoltaic array. Since the maximization of power in the load is ultimately desirable, this study focuses on the maximization of power to the load. The power transferred to load under different shading patterns is analyzed and the results of the study are demonstrated through simulation and experimental results. In this paper emerging technologies are discussed. The output of a photovoltaic panel is affected by the changing atmospheric conditions such as solar Insolation, temperature partial shading, dust, etc. These factors have also being incorporated in the various techniques discussed.

Keywords: Efficiency, MPPT, Self-Cleaning, Partial Shading, Temperature

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I. INTRODUCTION

Solar power is the transformation of solar radiation into electricity, either directly using photovoltaic or indirectly using concentrated solar power. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large part of solar radiation into a small beam. Photovoltaic cells convert light into an electric current using the PV effect. The international energyagency projected in 2014 that under its "high renewable" scenario, by 2050, solar photovoltaic's and concentrated solar power would contribute about 16 and 11 percent, respectively, of the worldwide electricity consumption, and solar would be the world's biggest source of electricity. Most solar PV installations would be in India and china. Photovoltaic's were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop photovoltaic system.[1-2] As the cost of solar electricity has fallen, the number of grid-connected SPV systems has grown into the millions and utility-scale solar power stations with hundreds of megawatts are being built. SPV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the sun. The current largest PV power station in the world is the 850 (mw) megawatt Longyangxia dam solar park in Qinghai, China. Commercial concentrated solar photovoltaic power plants were first developed in the 1980s. The 392 mw Ivanpah installation is the largest concentrating solar power plant in the world, located in the Mojave desert of California .a solar cell, or photovoltaic cell , is an electrical device that exchanges the energy of solar light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a procedure of photoelectric cell, distinct as a device whose electrical features, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of SPV modules, otherwise known as solar panels. Solar cells are defined as being photovoltaic, irrespective of whether the source is solar radiation or an artificial light. They are used as a photo detector (for example infrared detectors), detecting light or other electromagnetic radiation close the visible range, or calculating light intensity[3].

II. EFFECT OF SHADING

Shading can have a very large impact on the performance of solar photovoltaic panels. It is clear that the best solution is to escape shading altogether, though this is not possible in practice due to factors like cloud, rain, dust etc.The performance of the whole solar PV panel will significantly reduce. Solar PV panels actually consist of a number of solar PV cells that are wired together into a series circuit. This means that when the power output of a single cell is significantly reduced, the power output for the whole system in series is reduced to the level of current passing through the feeble cell[4-6]. Therefore, a small amount of shading can significantly reduce the performance of your whole solar PV panels system. One of the main causes of losses in energy generation within PV systems is the partial shading on photovoltaic (PV modules). These PV modules are composed of photovoltaic cells (PV cells) series or parallel connected, with diodes included in different configurations. The curve of a photovoltaic cell varies depending on the radiation received and its temperature. There are two typical configurations of bypass diodes overlapped and no-overlapped. It should be noted that the analysis in modules with overlapped diodes is a more complex one, because there may be different paths for current flow. This paper examines the individual behavior of a photovoltaic module and a photovoltaic array connected to an inverter with shadows in both cases. The decrease in power generation is proportional to the shaded part and decrease in solar irradiance, thus introducing the theory of shading factor. While this theory is true for a single cell, the decrease in power at the module level is often distant from linearity with the shaded portion[7].

III. EFFECT OF PARTIAL SHADING IN SOLAR CELL

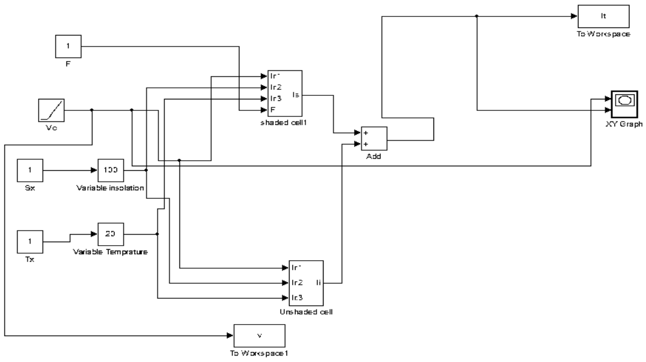

Figure 1: Parallel Connection under Shading for I-V Characteristics.

The above figure shows the interconnection of two parallel connected photovoltaic cells in which one photovoltaic cell is unhanded and the other is selected for shading conditions, the net output current is the sum of the output current of these two cells. The details of the output current block is shown in the below figure.

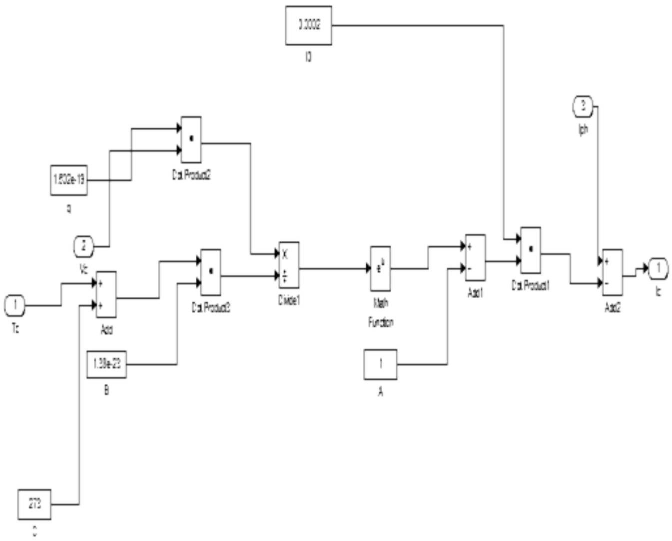

Figure 2: Ice Calculation Block

A number of series/parallel connected SPV modules are used to form a solar array for a desired voltage and current level. The major challenge in using a SPV source containing a number of cells in series is to deal with its non-linear internal resistance. The problem gets all the more complex when the array receives non-uniform irradiance (partially shading). In a solar panel spread over massive area, it is expected that shadow may fall over some of its cells due to tree leaves falling over it, birds or bird litters on the panel, shade of a nearby construction etc[8-10]. In a series connected string of solar cells, all the cells convey the same current. Even however a few cells under shade generate less photon current but these cells are also forced to carry the same current as the other completely illuminated cells.

The shaded cells may get reverse biased, acting as loads and draining power from fully illuminated cells. If the system is not appropriately protected, hot-spot problem (Quashing and Hamish 1996*)* can arise and in several cases, the system can be irreversibly damaged. Nowadays there is an increasing trend to integrate the SPV arrays at the design level in the building itself. In such cases it is tough to avoid partial shading of module due to near buildings throughout the day in all the seasons. In conventional SPV systems, those shadows lower the overall generation power to a large degree. Hence the SPV installation cost is increased, because the number of SPV modules must be increased, and as a result, SPV power generation will be less attractive. This kinds the study of partial shading of arrays a key issue. Moreover it is very important to understand the characteristics of solar photovoltaic under partial shaded conditions to use SPV installations effectively under all conditions. In recent years, the impact of partial shading on the SPV array performance has been widely discussed *(*Herrmann Et Al 1997, Kashia and Gautama 2003, Klink Et Al 2002, Whyte Et Al 2003*).* With a physical SPV module it is difficult to study the effects of partial shading since the field-testing is costly, time consuming and depends heavily on the prevailing weather condition. Moreover it is tough to maintain the same shade under variable numbers of shaded and fully illuminated cells throughout the experiment. However it is convenient to carry out the simulation study with the help of a computer model. In most of the studies *(*Rauschenbusch 1971, Alonso-Garcia Et Al 2006 b, Alonso-Garcia 2006 c, karate Et Al 2007*),* the effect of partial shading in reducing the output power of the SPV array has been discussed. But a little attention has been given as to how the power dissipated by the shaded cells is affecting the array life and utilization of the array for the worst shaded case. The work presented in this chapter is mainly concentrated to study the harmful effects of the shading patterns in basic configurations, that is, series and parallel connected modules. The comparison is made between these two connections. For other configuration types, a generalized mat lab programs have been developed which are capable of simulating any number of modules connected in series or parallel and any type of shading pattern.

IV. BASIC CONNECTION METHODS OF SPV ARRAY AND ASSOCIATED PROBLEMS

As with the connection of cells to form modules, a number of modules can be connected in series string to increase the voltage level, in parallel to increase the current level or in a combination of the two. The particular configuration depends on the current and voltage desires of the load.

Matching of the interconnected modules in respect of their outputs can maximize the efficiency of the array. The conventional SPV module is constructed of several SPV cells (normally 36 cells) connected in series. In the solar photovoltaic power generation system, multiple SPV modules are generally connected in series in order to obtain sufficient dc voltage. If there is one shaded module in a series connected array, it can then act as a load to the array. It may cause damage to the module due to the heavy current passing through it. To prevent this damage, bypass diodes are connected in anti-parallel with each module, and, in case of the module is shaded; the current may flow through the bypass diode rather than through the module. In series connected array, even the slightest shadow falling on a solar photovoltaic module causes a significant drop in generated power.

In parallel connected modules, if one module is severely shaded, or if there is a short circuit in one of the module, the blocking diode prevents the other strings from sending current backwards down the shaded or damaged string. Diodes placed in series with modules can perform the function of blocking currents from flowing back to the modules thus preventing the modules from becoming loads. When the non-shaded SPV modules and the shaded solar photovoltaic modules are connected in parallel, the generation voltage is fixed for each solar photovoltaic module and is uniform throughout the entire solar photovoltaic generation system, and the current generated from each SPV module flows without restriction. In other words, the output voltage of the SPV system becomes the voltage of a single module, and the output current becomes the sum of the currents in each module. In contrast, when each PV module is connected in series, the same current flows through each module and the output voltage becomes the sum of the voltages across each of the modules[11].

However, the voltage of each module is decided according to the generation current, which depends on the generation/shaded conditions. Therefore, the optimal generation voltages are not always obtained for each SPV module. In particular, when some of the SPV modules do not have sufficient generation current, the voltage of the SPV modules is greatly decreased and the resultant generation power is also greatly decreased. The performance analysis for series and parallel connected solar photovoltaic modules is analyzed in the following sections through consideration of the operating point.

V. CONCLUSION

Reverse biased characteristics of a solar photovoltaic cell are required to model the partial shading conditions of the SPV array. During reverse bias the shunt resistance rash is an important parameter affecting the behavior of the cell. Most of the researchers have either taken rash as constant or have neglected it. In this thesis an empirical relation has been established through a series of experiments and the insolation dependent resistance has been added in the model to improve its accuracy. The proposed model is more accurate when applied to analyze SPV module characteristics under partial shaded conditions. The developed model can be interfaced with power electronics circuits to see the impact of shading and can be used to develop new methods to reduce the adverse effects of partial shading. The proposed electronic load method is a simple circuit for display and recording of the characteristics in field conditions. Series connection of solar cells in an array is essential to get practically utilizable voltage. In series connection, the shaded cells may get reverse biased, acting as loads, draining power from fully illuminated cells. The impact of partial shading on series connected cells, series connected modules and parallel connected modules have been carried out. From the results, the following points have been concluded.

As there is a considerable power loss due to non regularity illumination of a series string care should be taken to see that all the cells connected in series receive the same illumination. Under different patterns of shading. Such care will give a better protection to the array and at the same time the total energy output will also be higher.

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