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A Comprehensive Review of Partial Shading Analysis in a Solar PV Array

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Abstract - The global transition to sustainable energy sources has spotlighted the pivotal role of solar photovoltaic (PV) technology in mitigating environmental impacts and fostering a clean energy future. However, the efficiency and reliability of solar PV arrays are significantly affected by partial shading conditions, where specific portions of the array receive reduced sunlight. This paper presents a comprehensive review of the importance of analyzing solar PV arrays under partial shading conditions, exploring economic, technological, environmental, and regulatory dimensions.
This review paper provides a holistic understanding of why the scrutiny of solar PV arrays under partial shading conditions is indispensable. By synthesizing existing knowledge, the paper aims to contribute to the ongoing discourse on the importance of this research domain, calling for continued exploration and innovation in the quest for a sustainable and efficient solar energy landscape

Key Words: Introduction , Related work

1.INTRODUCTION

In the past years, traditional solar panels, often made of crystalline silicon, faced challenges in partial shading scenarios. When even a small portion of a solar panel is shaded, it can significantly reduce the overall efficiency of the entire panel. This is due to the fact that solar cells in series are affected by the lowest performing cell.

Addressing partial shading issues in solar photovoltaic (PV) systems relied heavily on traditional diode-based solutions, such as bypass diodes, to mitigate power losses caused by shaded cells or modules. These diodes were incorporated into the solar panels to create parallel paths, allowing current to bypass shaded areas. However, this approach had limitations, as it could only partially alleviate the impact of shading and often led to energy losses due to voltage drops and increased heat dissipation.

The latest technology in addressing partial shading challenges in solar photovoltaic (PV) systems revolves around advanced power electronics and smart algorithms. Multi-level inverters, such as cascaded H-bridge inverters, are increasingly employed to enhance the efficiency of PV systems under partial shading conditions. These inverters enable precise control of individual modules, minimizing energy losses by dynamically redistributing power among unaffected panels.

Nowadays Smart Panel Technologies involve the integration of intelligence at the individual solar panel level to optimize energy production and to mitigate the impact of partial shading. These panels are equipped with microinverters or DC-DC converters, enabling each module to operate independently and regulate voltage and current. By doing so, smart panels can maximize power output from each module, even in situations where parts of the array are shaded.

This paper endeavors to provide a comprehensive review of the importance of analyzing solar PV arrays under partial shading conditions. Analyzing the partial shading of a photovoltaic (PV) array is important because partial shading can significantly impact the performance and efficiency of the PV system. When parts of the array are shaded, it creates variations in the amount of sunlight reaching different sections of the array, leading to differences in voltage and current outputs among the cells. This can result in hot spots, reduced power output, and potentially damage to the cells. By analyzing partial shading, we can optimize the design and layout of the PV array, implement bypass diodes to mitigate shading effects, and develop shading mitigation strategies to maximize energy production and system reliability

2. Related Work

In[1] The irradiation intensity is the primary catalyst for energy production in photovoltaic (PV) systems. Nevertheless, it alleviates partial shading (PS) by inhibiting power production, primarily in habitable metropolitan areas, owing to surrounding objects or high soiling rates, particularly in dry and semi-arid climates. Hence, the PV module’s location, orientation, and tilt angle significantly affect its performance and shorten its durability. Thus, this study undertakes a benchmark analysis of the two distinct panel positions’ performance using PSIM and MATLAB software simulations and an actual practical test. A visual inspection of a solar powerplant in Morocco’s Green Energy Park is the origin of the survey concept ; it observes that the soil density consistently covers certain PV panel spots. In this context, the solar energy data of an intelligent home deployed in the earlier-mentioned research platform has been deployed to emulate the performance of future buildings challenged with various obstacles. Therefore, the roof-mounted PV system satisfied the home's energy demands. In the first scenario, the PV module is in portrait mode. In the second case, they are in landscape orientation. The findings of this investigation demonstrate that standard PV panels produce more power when arranged in a landscape configuration than in a portrait configuration, exhibiting a discrepancy of up to 1010 Wh for a modest PV system. Finally, this study suggests appropriate orientation and design recommendations for standard and advanced solar modules, mainly those deployed in arid and heavily populated urban regions featuring severe shading constraints.

In this contribution, the author introduces a theoretical, simulated, and concrete investigation of the different orientations of solar modules under partial shading and dust constraints. Furthermore, a simulation assignment is performed for conventional and advanced models to simulate the resulting energy required to ensure the injection of photovoltaic energy into new-generation power grids. This research focuses on photovoltaic installations located in areas with mandatory panel inclination and shading issues. This survey highlights certain main conclusions that can be summarized as follows: • Identifying the orientation of the cell subparts is recommended as a preliminary step to properly mount the PV modules under partial shading and dust accumulation conditions. • Improper orientation can lead to substantial energy losses exceeding 1000 Wh for a PV plant up to 3000 W when the PV panels are mounted in portrait mode. • Advanced MPPT inverter technology may provide different energy loss rates than those indicated in this study; however, the landscape is significantly superior to the portrait mode.

In[2] Solar system is the high-quality and trustworthy supply of renewable energy. It is far contamination loose, fewer preservation, reusable and unfailing. The overall performance of photovoltaic (pv) machine is often stricken by radiation, module temperature and array configuration. The understanding of the shading impacts and their courting among the output powers of the pv array may be very essential in an effort to find a well overall performance of the pv system. partial shading is a case whilst the special modules of the array received a different irradiance level. This shadow can be both to expect due to extraordinary situations: neighbour constructing, close by tree or tough to are expecting due to clouds or building. the cause of this paper is to take a look at and illustrate the outcomes of partial shading with bypass diode and without bypass diode on the I(V) and P(V) traits of the photovoltaic panel. This is performed via using simulation using MATLAB/Simulink. This paper shows more feature changes compared to shaded and unshaded conditions. All results are presented graphically.

This paper presented the effects of partial shading with bypass diode and without bypass diode on the I-V and P-V characteristics of the photovoltaic array. The simulations where performed out in MATLAB environment which offers a good understanding of the effect of partial shading on the photovoltaic system.

In[3] Photovoltaic system performance is considerably influenced by solar radiation, shading, temperature, etc. Shading can be occurred by clouds, nearby buildings, trees. Under shading condition, the output plot of the P-V system gets affected. Therefore, it is of great importance to predict the output plot of the P-V system. This paper describes the output characteristics of the P-V system under different shading conditions by the use of MATLAB simulation. This paper is also useful in studying shading effect on a P-V panel having a different connection. The different configuration in P-V panel greatly effects maximum power under non-uniform irradiance due to the partially shaded condition. This proposed Simulink model can be used to simulate the behaviour of a various range of photovoltaic system from one P-V module to multidimensional P-V structure.

This proposed model can be used to analyse the effect of shading on the solar panel. This model could predict the characteristics of the P-V panel for specific shading pattern. The use of bypass diode allows extracting more power from the solar panel under the different shaded condition, as compared to without diode case. In this simulation we get more than one maximum power peak. Therefore it will help in developing new MPPT technique.

In[4] This paper analyses the effects of partial shading on energy output of different solar photovoltaic array configurations and to mitigate the mismatch loss faced in solar photovoltaic system. In this study, the photovoltaic power system is designed to electrify the building of the university that is situated in Insein Township, Yangon division, Myanmar. Geographically, it is located at latitude 16˚ 8' N and longitude 96°50'E. The power demand of the proposed building is estimated as 17.64kW. The considered photovoltaic power system consists of 60 modules. Each module is 300W multi-crystalline module. The photovoltaic array configurations are modelled in MATLAB/SIMULINK with four different configurations. These configurations are Series Parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL) and Honey Comb (HC). After modelling, the different configurations are simulated and compared under various partial shaded conditions such as 200W/m2, 500W/m2, 800W/m2. Finally, it is observed that the best configuration is TCT that can reduce the mismatch losses under partial shading conditions.

In this paper different configuration like SP, TCT, BL and HC configuration is simulated with the help of MATLAB/SIMULINK and their performance is compared under various partial shading conditions. It is reported in literature that TCT performs better under partial shading condition. TCT interconnection has a substantial reduction in mismatch losses that occur due to partial shading beside to it has greater reliability comparable with SP and BL

In[5] The global electrical energy consumption is steadily rising and therefore there is a continuous demand to increase the power generation capacity. Increasing prices of fossil fuels and awareness of global warming have drawn attention towards the use of Solar Photo Voltaic Cells as an alternative source of electric power. Experimental determination of voltage-current characteristic of a solar panel is required for its simulation and setting the parameters of the circuit for extracting maximum power. An attempt to determine such a characteristic by connecting a variable resistance across the panel and measuring the voltage and current by meters is not accurate all the times due to varying cloud positions and temperature during the experiment. A method to quickly draw the characteristics and recording the result using an electronic load has been presented in this paper.

As a single cell produces voltage around 0.7V only, a number of cells are connected in series forming a Solar Photo Voltaic Array (SPVA) to produce voltage levels of practical use. For a practical SPVA spread over large area, it is difficult to maintain uniform insolation on all the cells at all times and the performance of the array is affected. Such a problem may arise due to passing clouds, shadow caused by neighbouring buildings, trees etc. Under this non uniform insolated condition the P-V characteristics get more complex with multiple peaks. To get the maximum power from the SPVA under all conditions of insolation, it is very important to understand and predict the P-V characteristics. In this paper, characteristics of three solar panels receiving different insolations and connected in series have been drawn using fast electronic load. A method to add the characteristics of individual panels to obtain the combined characteristics has also been presented.

In a SPVA non-uniform insolation can damage poorly illuminated cells. A large proportion of electrical power generated by highly illuminated cells is wasted as heat in poorly illuminated cells. Use of bypass diodes can save the poorly illuminated panels from damage and also make this energy available to the load. P-V characteristics under non uniform insolation with bypass diodes contain multiple peaks. The magnitude of the global maxima is dependent on the array configuration and shading patterns. As the developed model is circuit oriented model, PSpice , it can be used readily to predetermine the behavior of any SPV array having different number of cells in series and parallel, different number of bypass diodes and shadow conditions. A method to quickly draw I-V characteristics of SPV using MOSFET as the load resistance has been presented. The electronic load is useful for observing panel characteristics in the field conditions.

3. CONCLUSIONS

After a thorough analysis of the above papers under consideration, it is evident that [1] emerges as the most compelling and noteworthy. This paper provides a comprehensive analysis of the performance of PV module positions under partial shading conditions, offering valuable insights into the impact of module positioning on energy output. It also discusses the use of bypass diodes and maximum power point tracking (MPPT) techniques to mitigate the effects of partial shading on PV systems. Additionally, the study introduces a reference model developed using artificial neural networks (ANN) to estimate the power output of the PV system under various conditions, providing practical recommendations for improved energy production. Overall, the paper presents significant contributions to the understanding of PV system performance under partial shading conditions and offers valuable insights for future research and practical applications in the field of solar energy.

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