A comprehensive review on PV configurations to maximize power under partial shading

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Abstract—Partial shading is the condition where PV array experiences different level of irradiances on it which results significant reduction in output power. To handle that issue, PV modules are connected in various configurations as reported in the literature. Different connection schemes of the PV modules provide alternative paths to current flow that eventually improve power attainment under partial shading. A comprehensive study of literature shows that PV modules are connected under different schemes namely simple series (SS), parallel (P), series-parallel (SP), total-cross-tied (TCT), bridge-linked (BL) and honey-comb (HC). In this paper, a comprehensive review is performed to highlight the advantages and limitations of each scheme. To validate the findings from literature review, several experiments are carried out on various configurations in MATLAB Simulink. Three different cases namely unshaded, corner shaded and centre shaded conditions are used in the experiments to analyse the output characteristics. The superiority of various configurations in distinct operating conditions is demonstrated by comparing their maximum power output, relative power loss and fill factor. Based on the results, several recommendations are made on how to handle partial shading by using different PV configurations.

***Index Terms*—PV Configuration, Maximum Power, Irradiance Mismatch; Partial Shading, PV, Solar**

I. INTRODUCTION

The reserve of fossil fuels as non-renewable energy is depleting and general demand of power is increasing over the years. This motivates the growing in demand of renewable energy. Therefore, demand of energy harnessed from PV (Photovoltaic) modules is increasing gradually in recent years. Solar PV plays an important role in the generation of electrical energy in distributed system and also in standalone applications. This is due to the fact that PV is a source of renewable and sustainable energy. Besides, the average selling price of PV modules is decreasing over the years as researched in [1]. Despite these advantages, it has to be appreciated that the efficiency of PV modules are very low (10-25% in general). On top of that, power attainment from PV modules varies with irradiance and temperature. Thus, throughout the day maximum efficiency cannot be ensured. Besides, PV array lose power continuously when irradiance levels are different on different modules connected together. The phenomenon when the respective PV modules on the arrays connected together are receiving different irradiance or insolation levels is known as partial shading. It can be caused by passing clouds, tree shadows, dust and bird litters. When partial shading occurs, the output power at maximum power point (MPP) of the shaded cell is reduced and this causes mismatch in the PV modules [2]. Consequently, the lower current production causes circulating current in the shaded PV cell which can increase the temperature in the cell due to mismatch losses. The phenomenon is commonly known as hot spot and can bring permanent damage to the PV cell. However, this is easily overcome by the use of bypass diode but this further causes the output performance of the PV module to be affected. Multiple peaks in the P-V characteristics of the output of the PV modules will be created due to bypassing of PV cells [3]. Consequently, smart MPPT algorithms are needed to be deployed to handle such issue.

Apart from MPPT algorithms, effect of partial shading can be mitigated by choosing a suitable configuration of PV modules. The current existing configurations include simple series (SS) [4], parallel (P) [5], series-parallel (SP) [6], total-cross-tied (TCT) [7], bridge-linked (BL) [8] and honey-comb (HC) [9].

In this paper, a comprehensive study is carried out on the different configurations of PV modules. PV configurations are thoroughly analysed and their advantages and limitations are highlighted. To validate the ideas from the review, experiments are carried out in MATLAB Simulink. Based on the simulation result, performance of the different configurations is compared for their ability to provide maximum power under certain conditions. Performance comparison provides recommendations on under which scenario which configuration is the most suitable to handle partial shading. It is expected that, this paper will be a one-stop reference for new researchers who are embarking their journey in PV system research.

II. PV CONFIGURATIONS

It is demonstrated through experimentation in [10] that more power can be generated at the output of solar PV modules when correct or suitable configurations of PV modules is implemented considering respective scenarios. Connecting the PV modules in series increases the open-circuit voltage while connecting in parallel increases the short-circuit current. Hence, solar PV systems uses the various configurations to achieve voltage and current levels at output as desired [11]. Moreover, it is to be noted that TCT, BL and HC are commonly known as the cross ties configurations due to the ties connected in between the strings of the PV modules.

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