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Analysis and Comparison of MPPT Based PV System Under Partial Shading Conditions with Different Inverter Configuration

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Abstract: The variation in outcomes of PV module such as voltage, current, power and efficiency, when connected to load through different inverters under partial shading condition is analyzed in this paper. In this paper attempts are made to understand the merits and demerits of central inverters and string inverters when connected with P_V array, by comparing and verify the simulation outcome. The string inverter scheme with diode connections could have major role in improving efficiency, reliability and performances.

Keywords: Solar panel, MPP Tracker, Cuk dc/dc converters, Matlab.

1. INTRODUCTION

Light energy is mostly available in atmosphere making use of this energy to produce electric energy could meet day by day increase in demand of electric energy [1] [2]. Solar panel helps in converting solar energy to electric energy, but cost and less efficiency of these panels makes it less in demand. Output power of P_V modules relay on insolation rate of sun rays hence a MPPT method is essential to assure peak output power as possible is generated. Most of the algorithms have been successfully track MPP under normal light conditions, where only one MPP exists in the P_V curve, but the situation is different in the case of partial shading, where in P_V curve there exist number of MPPs, the ordinary algorithms fails to identify the largest value among these MPPs, therefore the overall efficiency is reduced. During uneven light situations the peaks in the P–V curve occur nearly 0.8 times of Voc [3]. Also peak value has a tendency to increase before the highest value among number of MPPs obtained during uneven insolation and decrease after the same. A modified INC algorithm method [4]-[8] which tracks highest value among number of MPPs obtained during uneven insolation conditions and uneven load conditions at the output of Cuk converter is used in this paper.

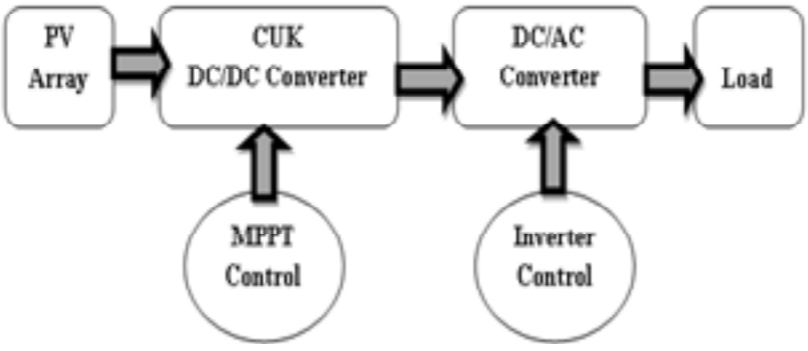

Figure 1: Skelton of the solar model

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2. UNDER UNEVEN INSOLATION

A number of parallel or series connected P_V cells form a P_V array. Output power from the P_V array is the integral of the power obtained from each P_V cells. If sufficient solar irradiation is not available for a P_V module as in figure 2 it decays the power produced by the nearby P_V modules [9]. P_V module which is shaded forcibly operates at the non conduction mode instead of conduction mode and instead of a power source it will act as a load. This may results in power drop and also produce local heat thereby the shaded P_V module is permanently damaged. Hence, diodes are connected [10] in parallel to protect P_V module from these so caused damages. As shown in figure 2, free wheel diodes are added into the P_V system configuration, to protect the P_V modules from hotspot formation during uneven shading. The free wheel diodes are reverse biased under uniform solar irradiation level, and have no action at that time. Figure 3 shows the P_V characteristics [11] at normal and abnormal light insolation of a module. I*ao* is the operating current of the P_V array. During uneven insolation condition, the flywheel diode is in conduction mode and the current flows through it and P_V module is protected.

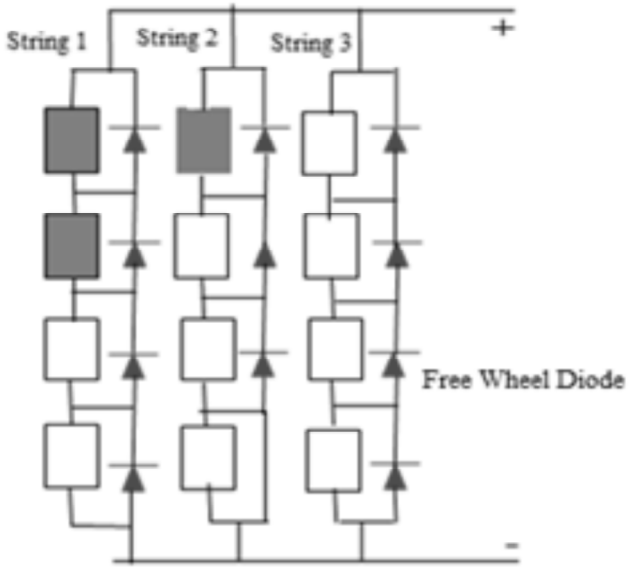

Figure 2: PV module with free wheel diode showing partial shading condition.

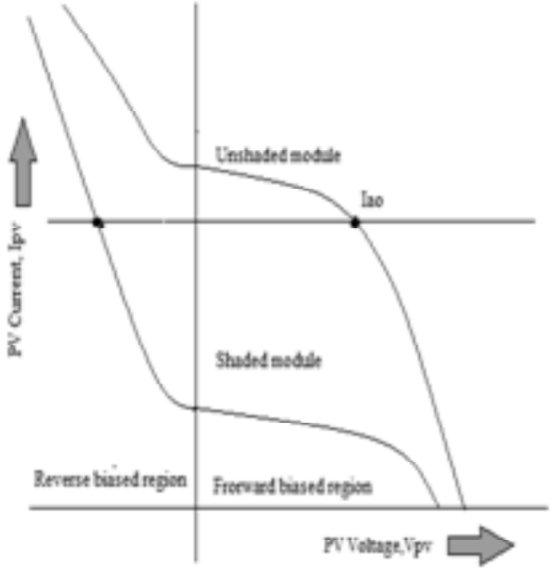

Figure 3: Characteristics of P_V module.

3. MODIFIED INC MPPT TECHNIQUE FOR PARTIAL SHADING CONDITION

In this MPPT technique [4], some crucial observations under uneven shading conditions such as the occurrence of peaks at the 0.8 times of module open circuit voltage and peak's magnitude will have a trend of decreasing and increasing. When travel all-around the P_V curve there will be increment in peak values until the global maximum is reached, and after that the peak will decrease. From the above mentioned crucial observations, some conclusion is made. The highest value among number of MPPs obtained during uneven insolation is identified at the centre of three seriate peaks or in another case the highest value among number of MPPs obtained during uneven insolation is situated at either at the left most position of the curve or at the right most position of the curve. Hence, there are only three possible types of multiple peaks in P_V curve. In initial type the highest value among number of MPPs obtained during uneven insolation is in between of the others local MPPs. The remaining possibilities are the location of the highest value among number of MPPs obtained during uneven insolation at the leftmost position of the P_V curve or rightmost position of the P_V curve, and if the peaks are further away from the highest MPP the magnitude will be decreasing. This algorithm tracks three seriate peaks and pinpoints the one which has the maximum or high peaks magnitude among all the MPPs. If the GMPP is not found in the middle of the three seriate peaks, it will keep searching unless the GMPP is in the middle or until the end of the P_V curve where the minimum or maximum possible voltage is achieved.

4. DC–DC CONVERTER

Figure 4 shows arrangements for Cuk converter. Its output may be below or above the input [12]. When the source voltage is applied, switch *Q* is in off state, diode is in conduction state and capacitor gets charged through *L*1, diode and input supply *Vs*. Working of circuit can be explained in section wise, In first section when switch *Q* is active the inductor *L*1 gets charged, simultaneously the diode get turned off as it is reverse biased by capacitor *C*1. The *C*1 discharges through *L*2 and the load. In second mode switch *Q* is switched off capacitor *C*1 charged from supply and *L*2 supply the load. When diode is on and *Q* is off and when *Q* is on diode is off.

The average output voltage, $Vav = \frac{DVs}{1-D}$ Where, *D* is duty cycle.

5. CENTRAL AND STRING INVERTERS

When a number of series connected P_V modules joined with an inverter, central inverters is formed [13]-[18]. Two types of configuration are presented in figure 5a and 5b; first one with central dc/dc converter and central inverter and another one are string dc/dc converter and central inverter configuration. When an inverter is connected to series connected P_V module and this combination is connected in parallel string inverters are formed.

5.1. Centralized Converter

In this, the voltage flowing through each string of the P_V modules is same [19]. Depending up on the intensity and depth of uneven shading, each string could have different P-V and I-V characteristics. The

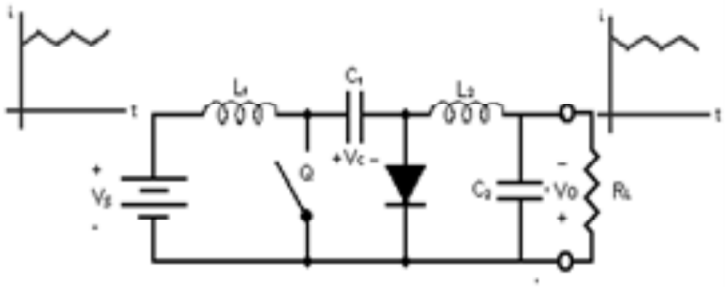

Figure 4: CUK Converter

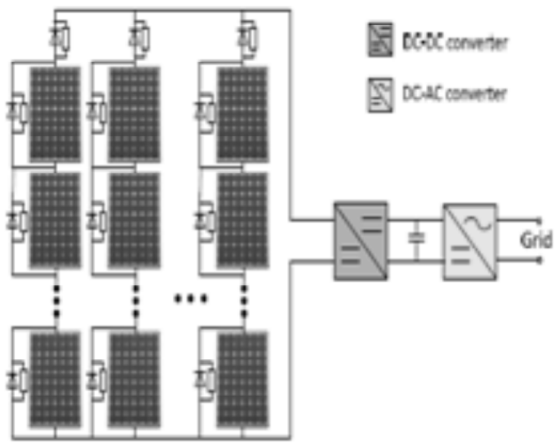

Figure 5a: Central inverter with central Dc/dc converter

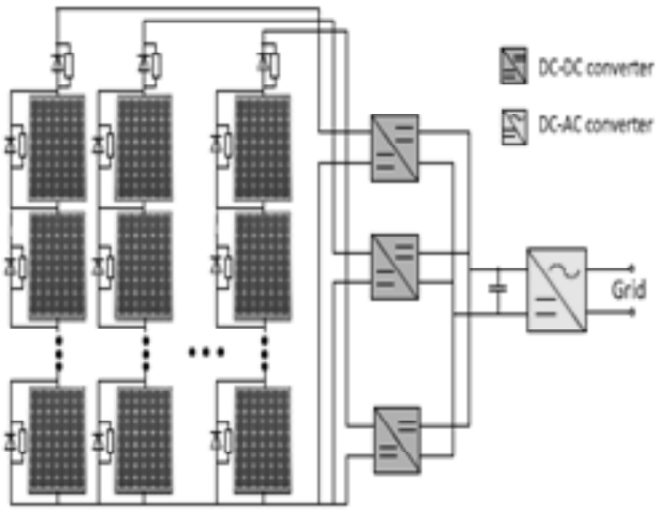

Figure 5b: Central inverter with string Dc/Dc converter

impact of the dusky cells to the P_V array features can be appreciably slow down by using freewheel diodes in each P_V cell. The shaded cell absorbs very small amount of power. Comparing the number of the shaded cells with the number of the unshaded cells if the number of unshaded cells are less then, the P-V characteristics of the P_V array is very close to the normal condition and also the effect of distribution of the shaded cells in the P_V array will be negligible. Furthermore, it is easy to manage the MPPT control of the P_V array even during uneven insolation condition. As freewheel diode are parallel with fewer cells in the P_V array, there will be a increment in peak power and the draw backs of multi-peak to the P_V curve will get reduced.

5.2. String Converter

In this voltage flows through each string of P_V modules will be different [20]-[23]. Hence, each string will be having independent characteristics. Output power of the array will be the integral sum of maximum power achieved by all panels. Under normal light condition, P_V characteristics of all strings will be equal. Under the MPPT control strategy, each string achieves different power. And the maximum power of one string multiplied by number of all strings gives total output power. When there are dusky cells in the P_V array, each string will be having different P-V characteristics depending on the how dusky cells are distributed in the P_V module. Maximum generated powers of the lowest and the highest dusky strings will give the total maximum power because its values lie in between these two extreme values.

If free wheel diodes are used within a module, the multiple peaks transfer the voltage range from low to high in general; thereby under the same shading conditions more outcomes is possible from individual string. If one free wheel diode is applied in even or odd to PV cells, there will be significant increase in the energy from each string and the optimum power of per string is very near to ideal peak power under the normal condition, thereby development and designing of MPPT algorithm become simpler.

6. RESULTS

In the analytical and comparative study of the power production using above said converter configurations a major problem arise is the amount of power that can be yielded from these two converter structures. Under partial shaded condition the INC MPPT tracks the maximum point effectively. The Cuk converter improves the output and is released to the inverter. The analysis with string inverter and central inverter is separately done. The outputs are compared.

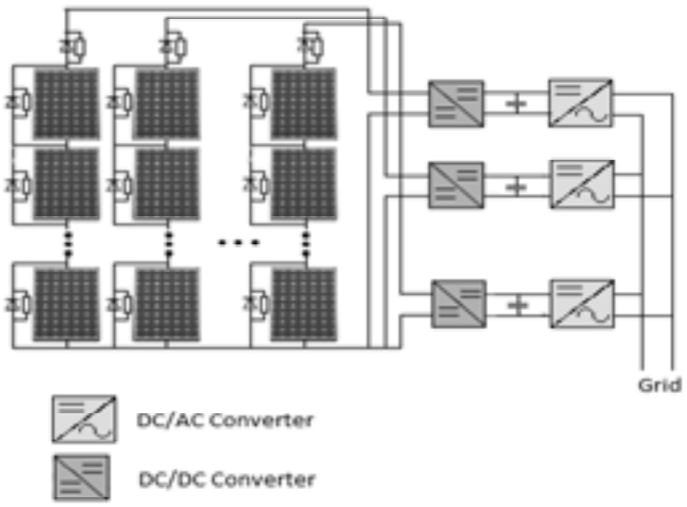

Figure 6: String inverter with string dc/dc converter

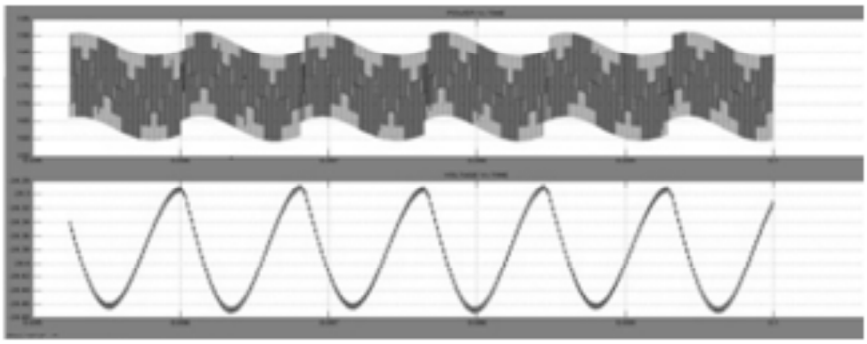

Figure 7: Output Voltage and Power of CUK with Modified INC MPPT

Table 1
Power generated under shading condition

Configuration	*Shading factor*	
	50%	*100%*
String Inverter	19.112 KW	19.101kW
Central Inverter	19.061 KW	19.047 KW

The figure 7 shows the voltage and power of Cuk converter with improved incremental conductance method. The maximum power that can be produced by means of these converter configurations with freewheel diode under 50% and 100% shading conditions is compared in Table 1. In this power output of string inverter is slightly more than that of central inverter.

7. CONCLUSION

A comparison of the outcomes of a P_V system with two converters, (central and string) in energy extraction is made in this paper. The paper aims to analyze how much the property of P_V array is affected by low insolation rate, by using above said two converters. In case of both converters under normal condition, property of P_V array is not affected. There is an improvement in efficiency while using freewheel diodes. Simulation studies show the difference among the MPP under uneven light conditions using two converters along with freewheel diodes. The most effective and economic way to achieve hike in efficiency and reliability of P_V system is by connecting String converter along with freewheel diode.

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