Dynamic and Static Reconfiguration Analysis of Solar PV Array

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Abstract:

Solar photovoltaic (PV) systems are increasingly attractive due to renewable in nature. Solar PV module technologies are paying more attention to enhance the energy production. Partial Shading (PS) will reduce the output power of the PV panel. The PS also causes problems such as mismatch loss and hotspots. This work proposes an analysis of the PS of Total Cross Tied (TCT), SuDoKu and Dynamic Reconfiguration of PV array with 3 × 3 PV modules. The proposed work will extract the maximum power extraction in dynamic reconfiguration under partial shading condition. The comparative investigation was presented for six shading patterns in the terms of Percentage Power Loss (PLL) and Fill Factor (FF). The percentage power loss and mismatch loss obtained in TCT and SuDoKu is 39.8% and 41.7% which is drastically reduced in dynamic reconfiguration is 33.2% and 23.64% respectively.

Keywords*: Solar PV, Partial Shading, Total Cross Tied, Percentage Power Loss, Fill Factor*

Introduction:

Conventional energy sources (oil, coal, nuclear) are depleting more amount of gas which leads to the greenhouse effect and global warming, so we move onto the renewable energy sources like solar, wind, fuel cells, biogas etc., [1,2]. Photovoltaic solar module technologies are focusing more on energy production. The cell types of solar PV are classified as monocrystalline, polycrystalline and bifacial. The electrical behavior of the PV module with VI characteristics depends on the irradiation level and temperature for this Standard Test Condition (STC) has been developed [3,4]. Different levels of partial shading occur due to the shadows of passing clouds, trees, dust, snow, nearby buildings etc., During the shading condition the shaded cell generates the least amount of current and results in an increase in temperature inside the cells and cause hot- spots, which destruction the PV modules. The authors carried out a comparative study among the basic interconnection schemes: series (S), series–parallel (SP), total cross tied (TCT), honey-comb (HC) and bridged-linked (BL) were proposed in many of the literature review. The proposed TCT power output increases by 105% compared to the existing TCT topology [5]. The main drawbacks of all reconfiguration techniques are very complicated to implement and also the cost requirements is very high.SuDoKu technique requires more electrical conductors [6].

However, in the dynamic reconfiguration technique, the adaptive parts of the photovoltaic modules are coupled to the fixed part of the photovoltaic modules in partial shading conditions. This method effectively reduces the mismatch losses. This technique requires an increased number of solid-state switches and sensors. To find the partial shading levels, this method measures short circuit current and open circuit voltage of the PV modules present in the array. The measurement is done by isolating load from PV array [7]. In this proposed work, we compared the TCT, SuDoKu and the Dynamic reconfiguration were carried out experimentally and found that dynamic reconfiguration shows the better performance when compared to the other configurations.

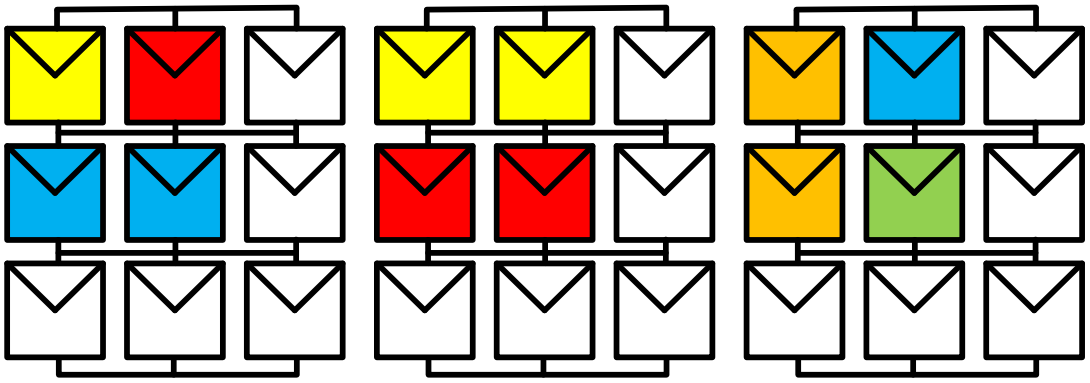
Experimental Setup:

The specification of the panel is represented in Table. 1.

Maximum Power (P_m)	30 W
Open Circuit Voltage (V_{oc})	21.60 V
Short Circuit Current (I_{sc})	1.83 A
Maximum voltage (V_{max})	18 V
Maximum Current (I_{max})	1.67 A

Table. 1. Specifications of the Panel

Results and Discussion:



(a) Type 1(b) Type 2 (c) Type 3

Fig. 1. Three types of shading patterns for 3×3 matrix

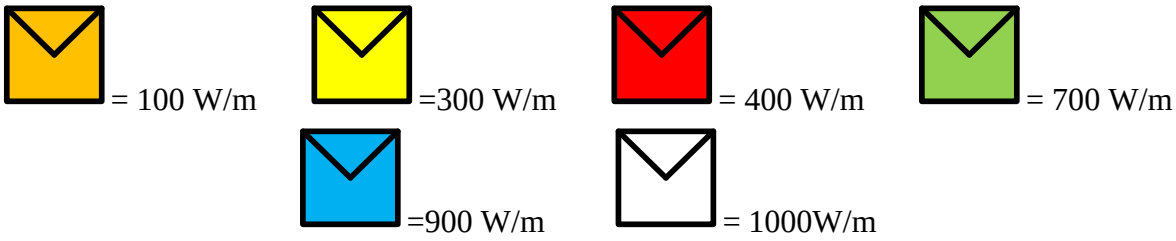


Fig. 2. Different shadings

TYPE 1

Methods	Current (A)	Voltage (V)	Power (W)	Mismatch Loss (%)	% Power Loss(%)	Fill Factor
TCT	2.84	54	153.4	59.6	43.1	0.43
SuDoKu	3.507	54	189.4	23.6	30	0.53
Dynamic	3.841	54	207.414	5.5	23.15	0.58

Table. 2. Comparison table for Type 1.

The 3×3 matrixes are categorized into three different shading groups as shown in Fig1.Type 1(a), the matrix A_{11}irradiation of 300 W/m, A_{21} has the irradiation of 400 W/m and $A_{12\&}A_{22}$ irradiation of 700 W/m. The remaining cell receives ($A_{13,}$ $A_{23,}$ $A_{31,}$ A_{32}, A_{33}) 1000W/m. The maximum power of 207W was obtained in dynamic type electrical reconfiguration. Compare with static reconfiguration methods SuDoKu and TCT has 189W and 153W congruently. In a static reconfiguration method, which needs extra DC cable wires. An Electrical type reconfiguration needs extra switches. Compare with Traditional TCT nearly 50% power loss reduced in dynamic type reconfiguration. The power loss of TCT is 43.1%, SuDoKu is 30% and Dynamic is 23% only. The maximum fill factor obtained at dynamic reconfiguration which is 0.58. The Fill factor slightly lower than dynamic reconfiguration obtained in SuDoKu method is 0.53. More than 25% reduced fill factor obtained in TCT 0.43.

Type 2

Methods	Current (A)	Voltage (V)	Power (W)	Mismatch Loss (%)	% Power Loss(%)	Fill Factor
TCT	2.672	54	144.3	47.7	46.5	0.40
SuDoKu	2.839	54	153.306	38.7	43.22	0.43
Dynamic	3.006	54	162.324	29.7	39.8	0.45

Table. 3. Comparison table for type 2.

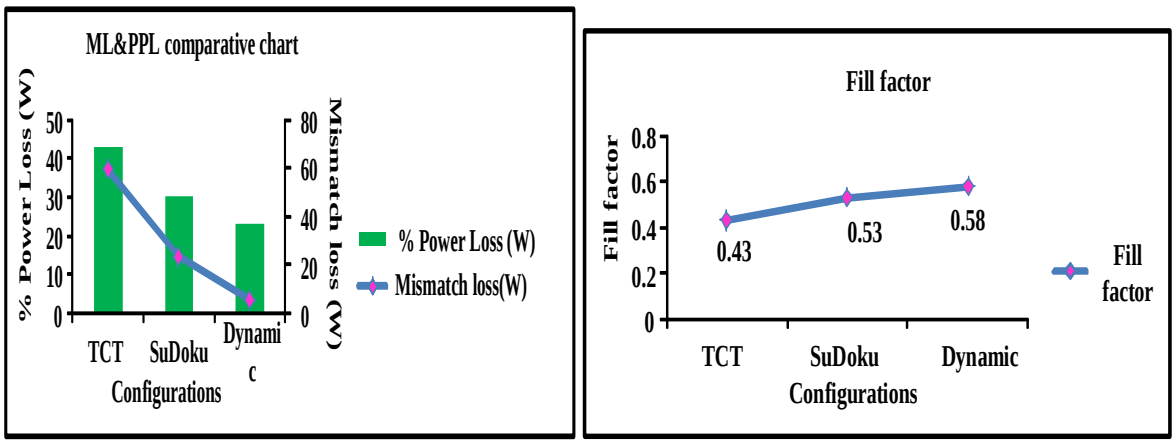
The 3×3 matrixes are categorized in to three different shading groups as shown Fig1.Type 1(b), the matrix $A_{11,}A_{21}$irradiation of 300 W/m, $A_{12\&}A_{22}$ irradiation of 400 W/m. The remaining cell receives ($A_{13,}$ $A_{23,}$ $A_{31,}$ A_{32}, A_{33}) 1000W/m. The maximum power 162 W obtained in dynamic type electrical reconfiguration. Compare with static reconfiguration methods Sudoku and TCT has 144 W and 153W congruently. The power loss of TCT in 46.5%, sudoku in 43.22%, and Dynamic is 29.7% only. The maximum fill factor obtained at dynamic reconfiguration is 0.45. The Fill factor slightly lower than dynamic obtained in SuDoKu method is 0.43and TCT 0.40. The mismatch loss obtained in TCT 47.7%, sudoku 38.7% and Dynamic 29.7%. Compare with TCT more than 37% reduced mismatch loss obtained in Dynamic reconfiguration.

Type 3

Methods	Current (A)	Voltage (V)	Power (W)	Mismatch Loss (%)	% Power Loss (%)	Fill factor
TCT	3.006	54	162.324	41.7	39.8	0.45
SuDoKu	3.006	54	162.324	41.7	39.8	0.45
Dynamic	3.34	54	180.36	23.64	33.2	0.50

Table. 4. Comparison table for type 3.

The 3×3 matrixes are categorized in to three different shading groups as shown Fig1.Type 1(c), the matrix A_{11},A_{12} irradiation of 100 W/m, A_{21} irradiation of 700 W/m, A_{22} irradiation of 900W/m The remaining receives (A_{13}, A_{23}, A_{31}, A_{32}, A_{33}) 1000W/m. The maximum power 180 W obtained in dynamic type electrical reconfiguration. Compare with static reconfiguration methods Sudoku and TCT has equal power 162W congruently. The power loss of TCT and sudoku in 39.8% and Dynamic is 33.2%. The maximum fill factor obtained at dynamic reconfiguration is 0.5. The Fill factor slightly lower than dynamic obtained in SuDoKu and TCT 0.45. The mismatch loss obtained in TCT and suDoKu 41.7% and Dynamic 23.64%. The graphical representation of all the three reconfiguration was shown in Fig. 3. And it clearly shows that the percentage of power loss is drastically reduced in dynamic compared to static reconfiguration.



Conclusion

The dynamic electrical reconfiguration method efficiently extracts the maximum power in the 3×3 solar PV array. Compare with static reconfiguration methods (TCT and SuDoKU) the maximum power extracted in dynamic reconfiguration. But it requires more number of switches. The main drawback of static reconfiguration method is extra DC cables required and not suitable for all the cases. Around three types of shading conditions the dynamic reconfiguration gives best results. The percentage power loss and mismatch loss obtained in TCT and SuDoKu is 39.8% and 41.7% which is drastically reduced in dynamic reconfiguration is 33.2% and 23.64% respectively.

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