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Electrical Faults and Their Impact on Performance of Solar PV Array

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Abstract:- The demand of energy is increasing exponentially in large amount since last two decades. So, to meet the demand of energy, a large amount of alternate source of energy is required. Among all the non-conventional energy resources, the photovoltaic energy is pollution free source of energy and widely adopted. Therefore, the stability and reliability is the large aspect for solar photovoltaic systems (SPV). The unusual situations like two node connections of different voltages, line to ground connection, etc leads to reduction in electricity generation. The electrical characteristics of photovoltaic array like current-voltage and power-voltage curves are non-linear due to which it is some more difficult to detect and classify the faults on photovoltaic array. In this research work various faults are created on a 4×4 PV array of 1596 W in MATLAB/Simulink environment.

Keywords:- *Electrical Faults, Solar Photovoltaic, PV Array, Partial Shading, Line-line Faults.*

I.INTRODUCTION

The unavailability of fossil fuels and the high demand of electricity is the major cause of high demand of non-conventional energy like wind and solar energy. The solar PV system is widely adopted renewable source of energy because of plenty availability of solar irradiation. The generated electricity from solar PV array is supplied to grid with the help of electronic converters [1], [2]. Since, among the total electricity generated by all sources, the amount of electricity generated by solar photovoltaic array is increasing day by day. Hence, the study of impact of electrical faults on the solar PV array performance is necessary.

A 4×4 PV array of 1596 W is modelled and shown in figure 1. The model consists of 16 photovoltaic modules and maximum output power of each module is 99.75 W. All the PV modules are connected with their bypass diodes and the blocking diodes are also connected in series with every rows of the array. The full specification of a single PV module is given in table 1.

The temporary fault and permanent fault are the two major classification of faults occur in the solar photovoltaic electricity generation system [3]. The faults under the category of permanent fault are line-line (LL) fault, line-ground fault (LG), open-circuit fault and degradation faults. The shading of photovoltaic module is the part of temporary faults [4]–[7]. These faults are sufficiently able to reduce the efficiency of the entire system. The four types of faults are shown in the figure 2. Line 1 is unintentionally connected with line 2 shown in figure 2 (a). Fa_1 and Fa_2 are two different condition of line-line faults [6]–[8]. Fb_1 and Fb_2 are the two situations of line-ground faults shown in figure 2 (b) [9], [10]. The degradation of PV module as Fc_1 and Fc_2 are shown in figure 2 (c) [11]. The temporary fault is shown in figure 2 (d). Third and fourth row of PV array is partially shaded to evaluate the performance of the system [12], [13].

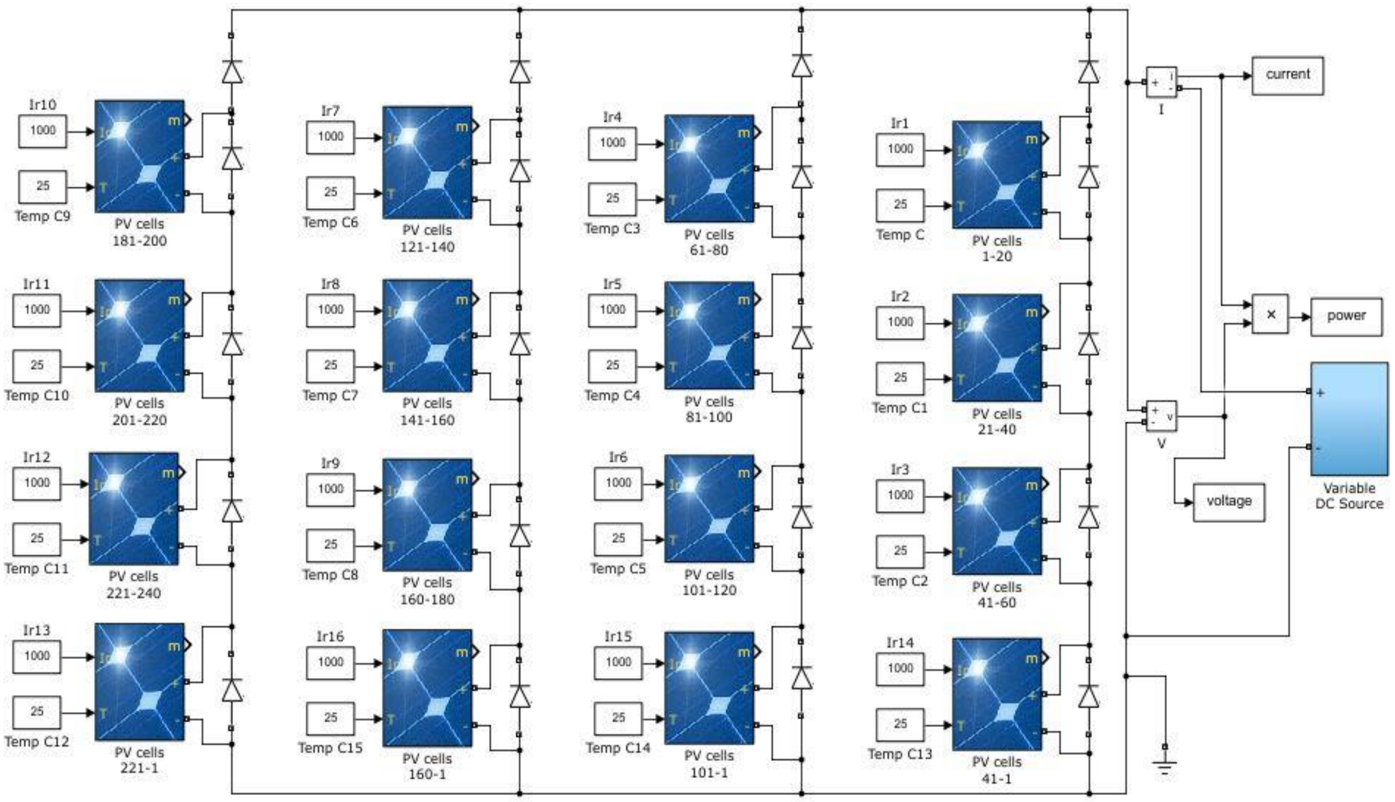
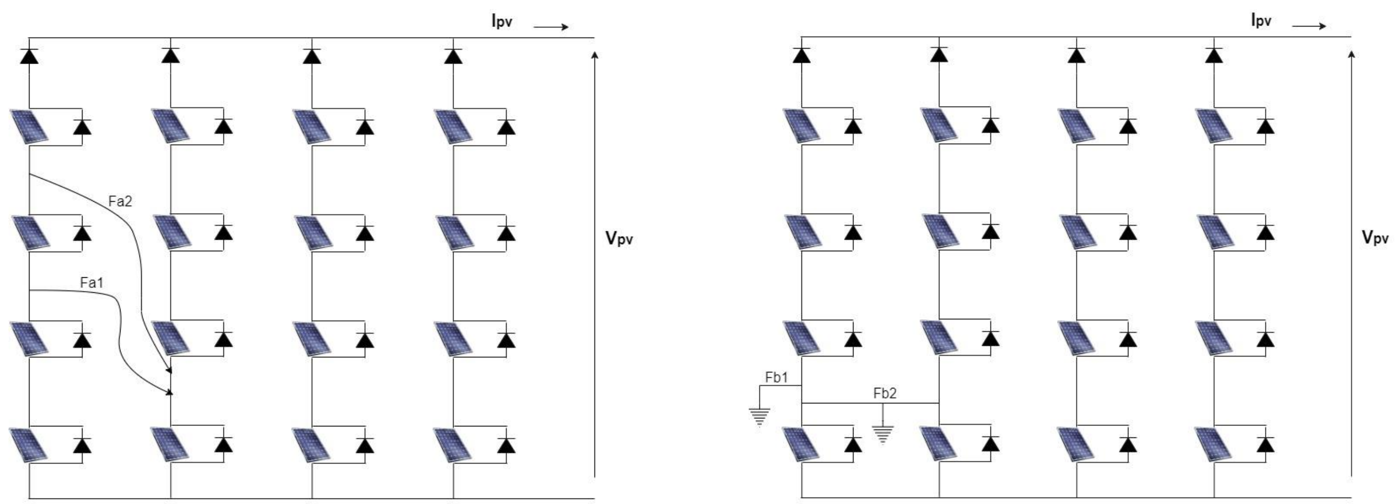


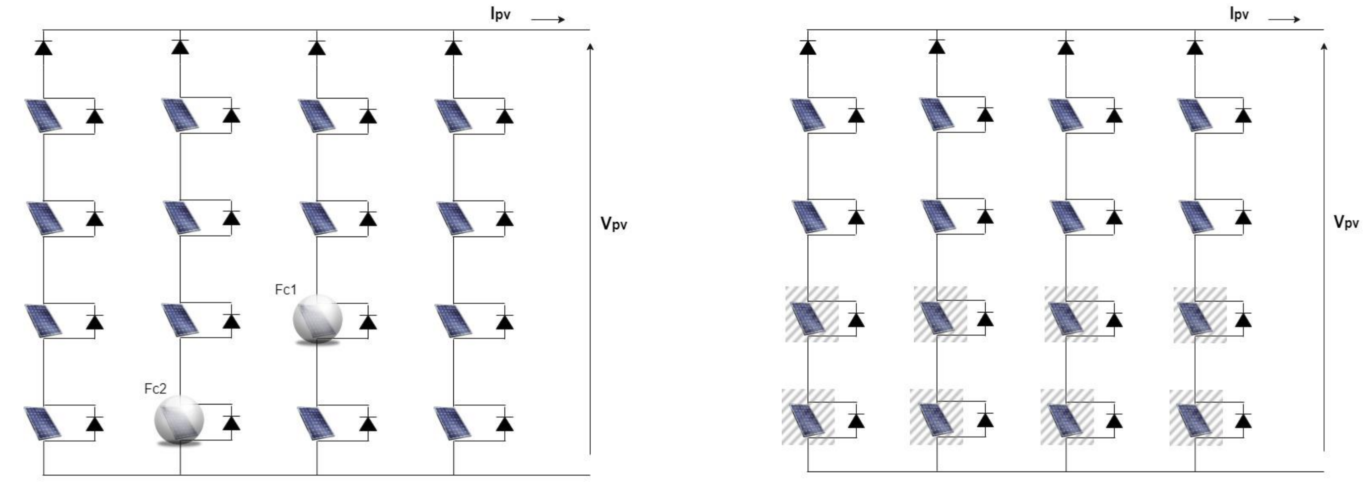
Figure 1: Solar photovoltaic generation model in MATLAB/Simulink

Table 1: Nexpower Technology NH-100 UT_4A solar panel electrical specification at STC

Parameter	Value
Maximum output power	99.75 W
Voltage at MPP (V_{mp})	37.5 V
Current at MPP (I_{mp})	2.66 A
Open-circuit voltage (V_{oc})	50.5 V
Short-circuit current (I_{sc})	3.3 A
Temperature coefficient of (V_{oc})	-0.306 %/ °C
Temperature coefficient of (I_{sc})	0.09 %/ °C
Shunt resistance (R_{sh})	77.04 ohm
Series resistance (R_{se})	2.74 ohm



(a) (b)



(c) (d)

Figure 2: (a) Line-line fault, (b) Line ground fault, (c) Degradation fault, (d) Partial shading

II.ANALYSIS OF VARIOUS FAULTS IN PHOTOVOLTAIC ARRAY

In this section various faults have been created in MATLAB/Simulink to analyse the impacts of electrical faults on photovoltaic array.

2.1. LL FAULT (Fa_1 & Fa_2)

In the first case of LL fault (Fa_1), fault is created by line 1 and line 2 with the mismatch of one module. Power, current and voltage waveforms are plotted shown in figure 3 (a). Due to LL fault, the changes in current and voltage are 0.73 A and 13.56 V respectively. Hence, the overall reduction in power is 244 W. In second case of LL fault (Fa_2), the mismatch of PV module is increased by one i.e. now the LL fault occurs with the two module mismatch. So, the drop in current and voltage are now 8.73 A and 26.8 V respectively shown in figure 3 (b).

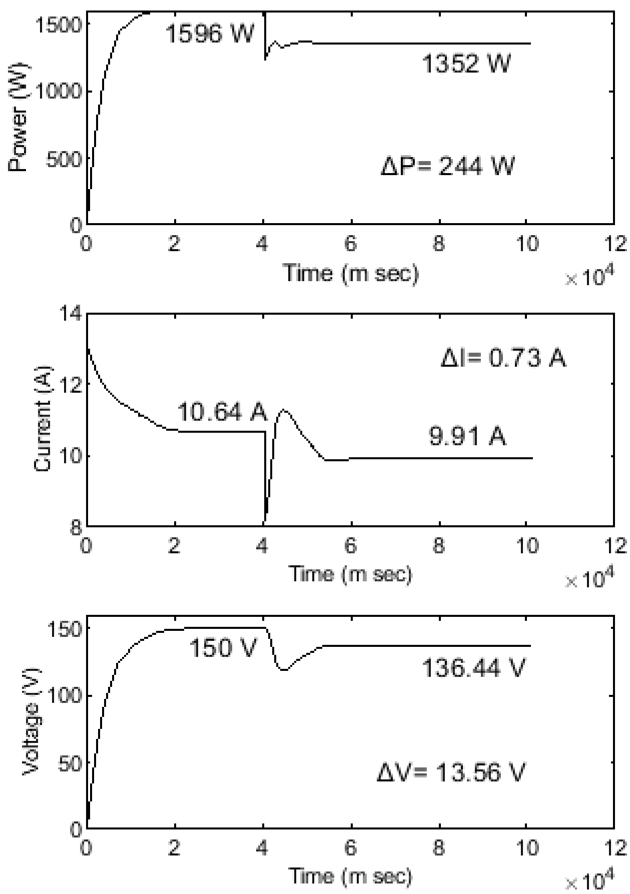


Figure 3 (a): LL fault (Fa_1)

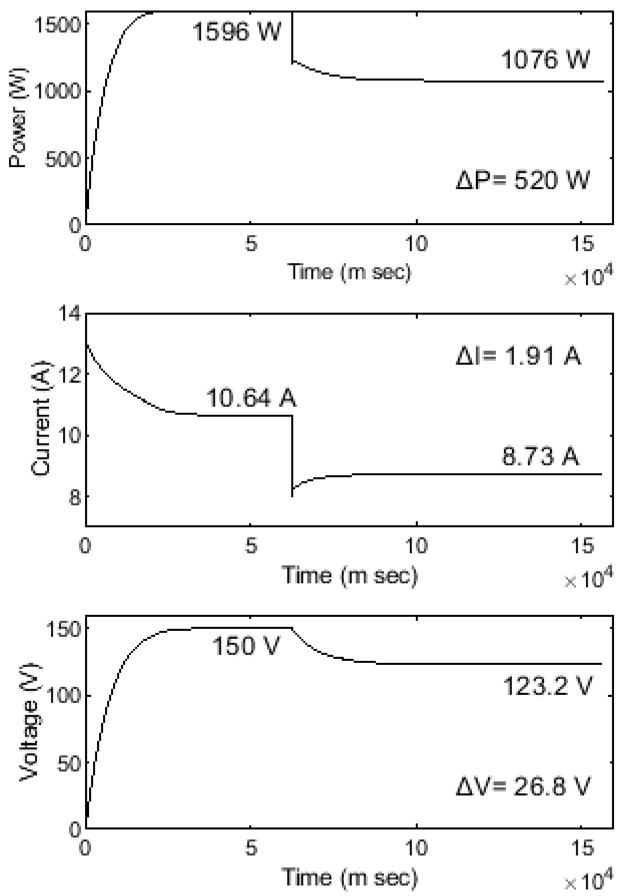


Figure 3 (b): LL fault (Fa_2)

2.2. LG FAULT (Fb_1 & Fb_2)

Line-ground fault is introduced in figure 2 (b). In the first case of LG fault (Fb_1), last module of the first column is connected with the ground. The drop reported in current and voltage is 0.7 A and 15 V respectively. This drop leads to reduction in output power by 254 W as shown in figure 4 (a). Another case of LG fault (Fb_2) is shown in figure 2 (b). In this case, two different line of PV array is shorted and connected to ground. Due to impact of this fault case the output current and voltage are decreased by 0.52 A and 25.42 V respectively. The overall power loss in this case is about 336 W as shown in figure 4 (b).

2.3. PARTIAL SHADING (P_1 & P_2)

Two different patterns of partial shading is created to study the shading effects. The shading pattern of both cases is given in table 2 and table 3. In the first case there are three different irradiation levels, so there will be three different power peaks in their power-voltage curve. Similarly, in second case there will be four different power peaks in power-voltage curve due to four different irradiation level. In the first case the drop reported in current, voltage and power is 1.67 A, 23.53 V and 462 W respectively and in the second case the drop in the respective parameters are 4.15 A, 58.29 V and 595 W as shown in figure 5 (a) and figure 5 (b).

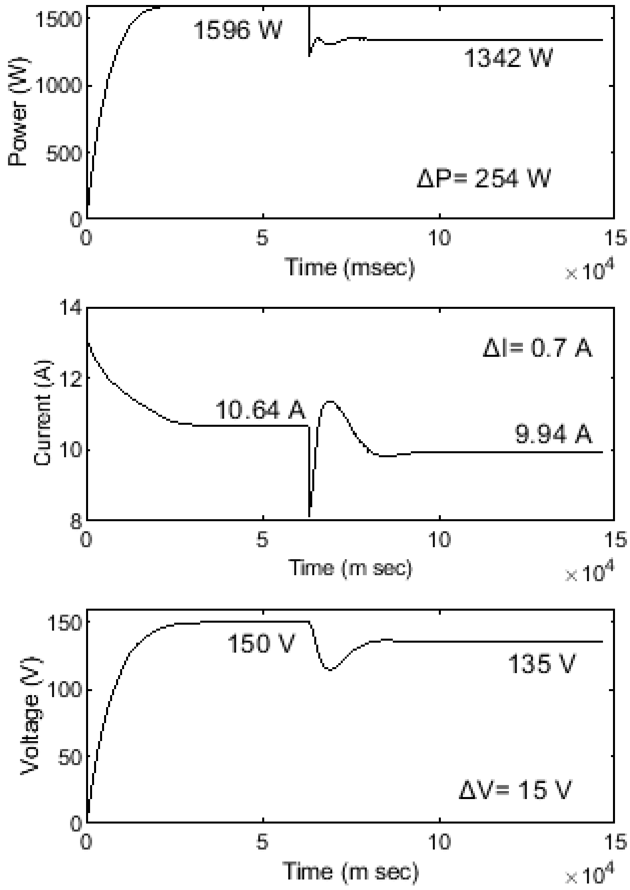


Figure 4 (a): Curve during LG fault (Fb_1)

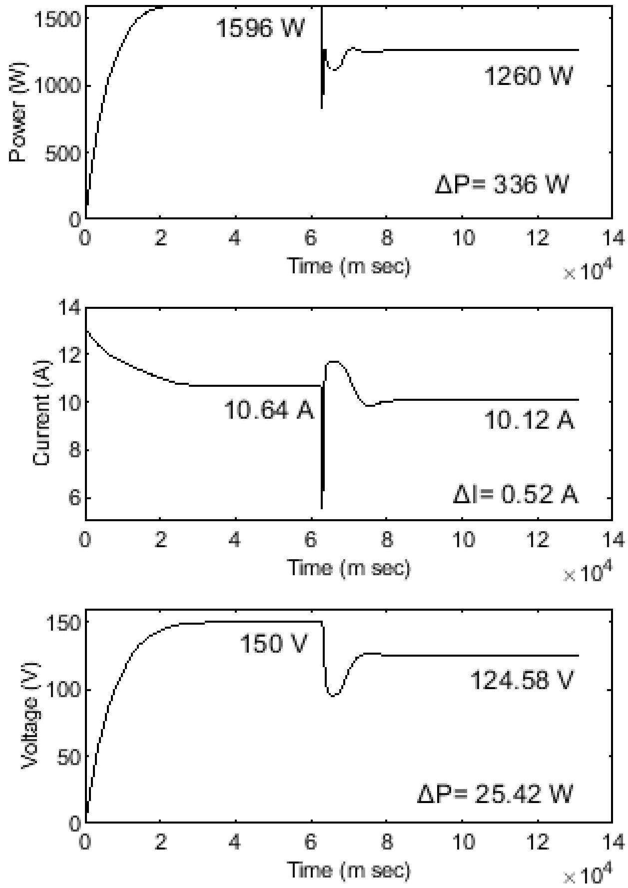


Figure 4 (b): Curve during LG fault (Fb_2)

Table 2: Partial shading pattern for case 1

1000 W/m^2	1000 W/m^2	1000 W/m^2	1000 W/m^2
1000 W/m^2	1000 W/m^2	1000 W/m^2	1000 W/m^2
800 W/m^2	800 W/m^2	800 W/m^2	800 W/m^2
700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2

Table 3: Partial shading pattern for case 2

900 W/m^2	900 W/m^2	900 W/m^2	900 W/m^2
700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2
500 W/m^2	500 W/m^2	500 W/m^2	500 W/m^2
300 W/m^2	300 W/m^2	300 W/m^2	300 W/m^2

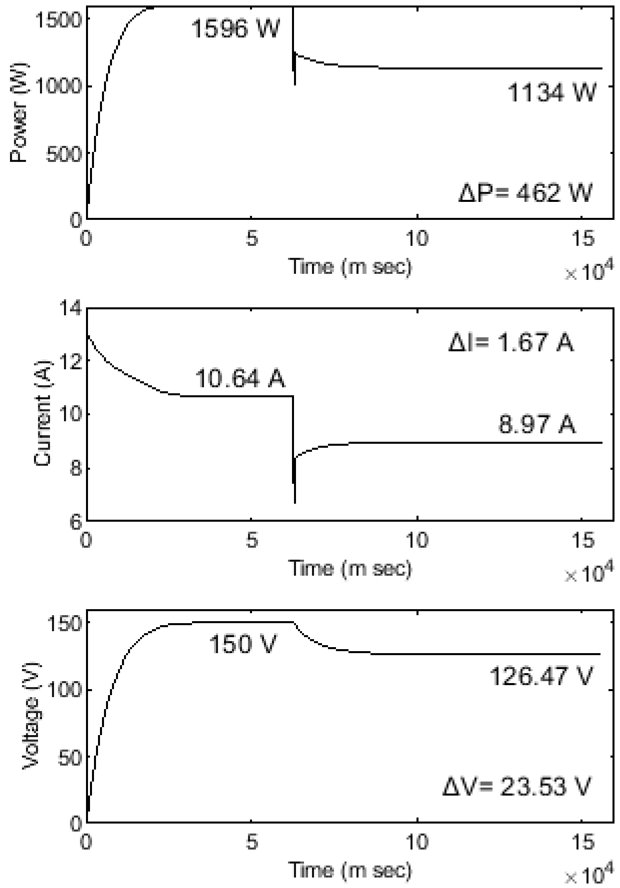


Figure 5 (a): Curve during partial shading Case 1

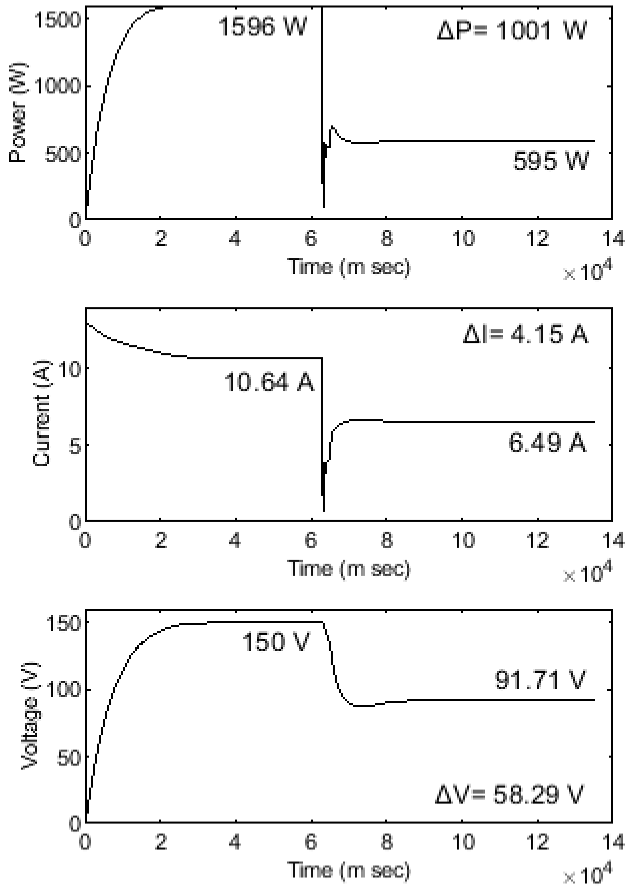


Figure 5 (b): Curve during partial shading Case 2

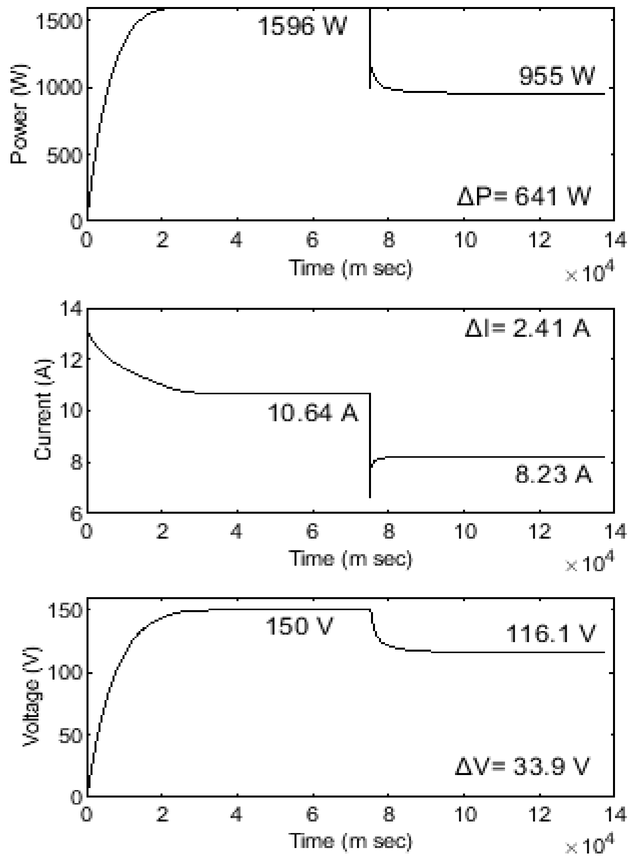


Figure 6 (a): Curve during uniform shading Case 1

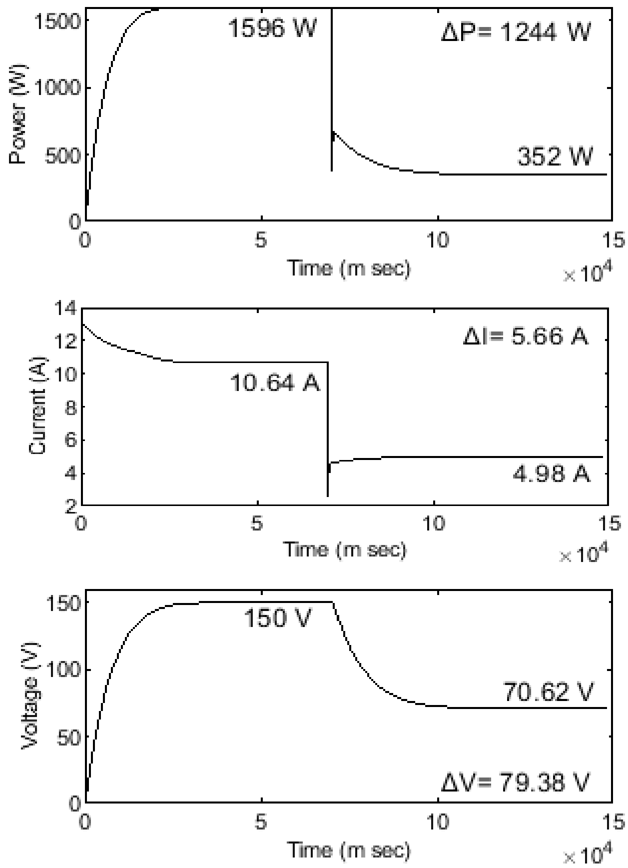


Figure 6 (b): Curve during uniform shading Case 2

2.4. UNIFORM SHADING

Uniform shading also causes the power loss in the PV generation system. Here, two cases of uniform shading are created to understand the shading behaviour of such cases. In the first case, the irradiation level for all module is 700 W/m^2. Due to the reduced irradiation the drop in current, voltage and power are 2.41 A, 33.9 V and 641 W respectively as shown in figure 6 (a). For the second case the uniform irradiation level is 400 W/m^2. In this case the drop in current, voltage and power are 5.66 A, 79.38 V and 1244 W respectively as shown in figure 6 (b).

Table 4: Uniform shading pattern for case 1

700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2
700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2
700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2
700 W/m^2	700 W/m^2	700 W/m^2	700 W/m^2

Table 5: Uniform shading pattern for case 2

400 W/m^2	400 W/m^2	400 W/m^2	400 W/m^2
400 W/m^2	400 W/m^2	400 W/m^2	400 W/m^2
400 W/m^2	400 W/m^2	400 W/m^2	400 W/m^2
400 W/m^2	400 W/m^2	400 W/m^2	400 W/m^2

III.CONCLUSION

Four types of electrical faults have been discussed. The summary of the faults effect is given in table 6. Results given in section 2 is exported from MATLAB/Simulink. The research work discussed in this paper conclude that the faults in solar photovoltaic array affects the electrical output parameters. The line-line and line-ground faults are permanent faults, therefore these faults should be removed from the array for reliable operation of the system. The partial shading and uniform shading conditions are the temporary faults but they also affects the system performance. The changes in basic electrical parameters due to faults are given in the table 6. Further, to distinguish the type of faults and to clear the faults various researches are in progress.

Table 6: Summary of faults and their impacts on electrical parameters

Fault Types		Pre-Fault			Post-Fault			Changes due to faults		
		P (W)	I (A)	V (V)	P (W)	I (A)	V (V)	ΔP (W)	ΔI (A)	ΔV (V)
LL fault	Fa_1	1596	10.64	150	1352	9.91	136.44	244	0.73	13.56
	Fa_2				1076	8.73	123.20	520	1.91	26.80
LG fault	Fb_1				1342	9.94	135.00	254	0.70	15.00
	Fb_2				1260	10.12	124.58	336	0.52	25.42
Partial Shading	Case 1				1134	8.97	126.47	462	1.67	23.53
	Case 2				1001	6.49	91.71	595	4.15	58.29
Uniform Shading	Case 1				955	8.23	116.10	641	2.41	33.90
	Case 2				352	4.98	70.62	1244	5.66	79.38

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