4. SIMULATION OF PARTIAL SHADING AND EFFECT ANALYSIS

4.1 OVERVIEW

The study begins with initial set-up for the environmental conditions prevailing in Chennai during the test period of January ~ December 2013. Typical Metrological Year (TMY) of the test site defining the test conditions was analysed and tabulated in Table 4.1. The Solar paths at Chennai, (Lat. 12.5°N, long. 80.2°E, alt. 19 m) have been extracted from the system for defining the test conditions and it is depicted in Figure. 4.1. The data of Sun elevation in Degrees with respect to Azimuth angle is reviewed for performing the research time during the day.

(Silvestre, 2002), Mat LAB etc. This experimental set-up has been simulated through a PV modeling and simulation software PVsyst V6.11. Simulation is performed to understand the characteristics and predicted performance of a poly crystalline PV module (110 Wp) and a mono crystalline PV module (250 Wp). Shade performance of PV cells was simulated with multiple option of single to multiple cells.

4.2 POLY CRYSTALLINE PV MODULE (110 W_p) SIMULATION

The simulation of a poly-crystalline Si 110 Wp PV module with 36 cells begins with characterization study. Normal and shaded performance of I-V and P-V curves are simulated with variability of number of cells shade, percentage of shade, with/without presence of by-pass diodes (BPD) under incident irradiance of 800 Wm^{-2}.

The temperature rise on the module cell is recorded for Data analysis.

Definition of a geographical site

Geographical Site: Chennai / India   Situation: Latitude 13°N Longitude 80.2°E

Time defined as : Zone UT+5.5   Altitude 19 m

Monthly Meteo Values Source   MeteoNorm 6.1 station

Table 4.1 Definition of a geographical site

Parameter	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Hor. Global	$kWh/m^2.day$	5.06	6.14	6.65	6.74	6.38	5.71	5.38	5.42	5.52	4.7	4.2	4.15	5.5
Hor. Diffuse	$kWh/m^2.day$	1.75	1.73	2.22	2.49	2.86	2.89	2.8	2.62	2.42	2.32	2.19	2.1	2.37
Extra terrestrial	$kWh/m^2.day$	8.51	9.36	10.11	10.56	10.6	10.51	10.51	10.52	10.25	9.59	8.72	8.22	9.79
Clearness Index	-	0.595	0.657	0.657	0.638	0.602	0.543	0.511	0.516	0.539	0.491	0.481	0.505	0.562
Ambient Temperature	°C	25.2	26.3	28.2	30	31.6	31.3	30.4	29.8	29.2	27.4	26.2	25	28.4
Wind Velocity	m/s	2	2.2	2.8	3.1	3.6	3.8	3.4	3.4	2.7	1.6	1.7	2.2	2.7

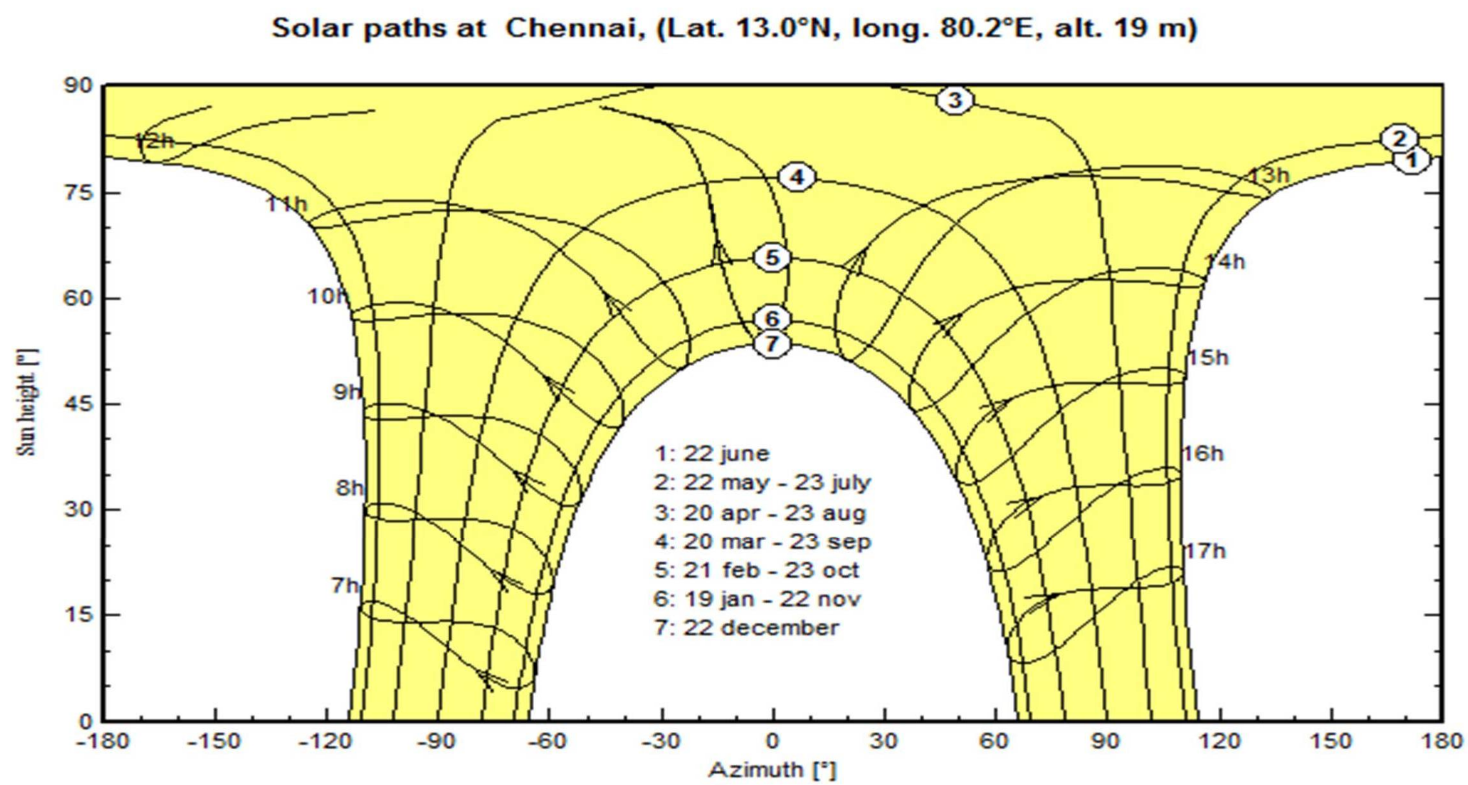

Figure 4.1 Solar Paths of Chennai

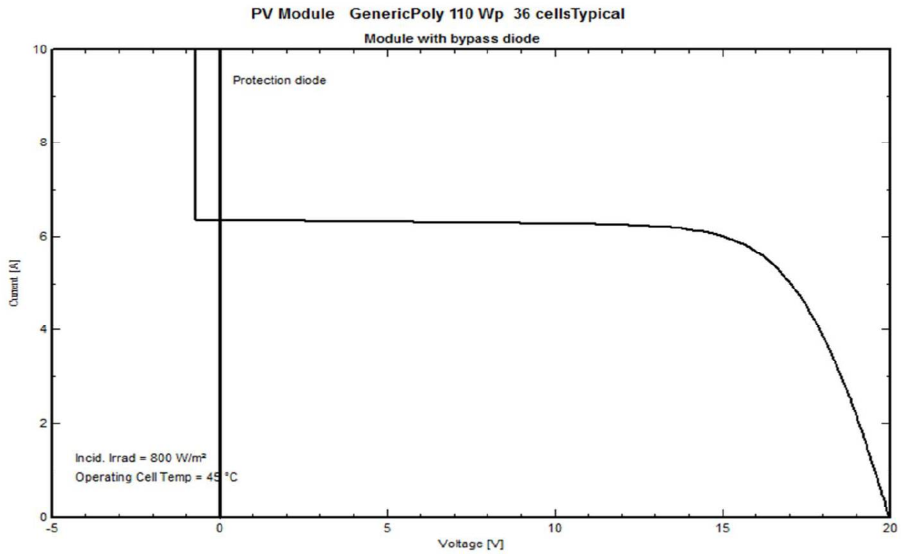

Figure 4.2 Normal I-V Characterisation (with BPD)

The curve is a standard I-V of a PV module under illuminiated operational state.

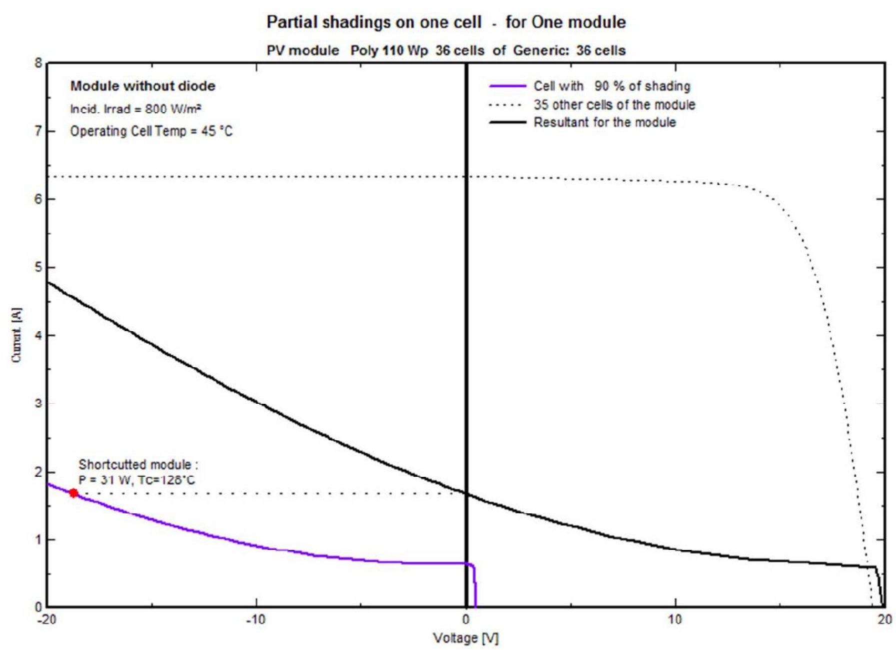

Figure 4.3 I-V Characteristics shift for one cell 90% shaded (without BPD)

This simulation in Figure. 4.3 is to understand the IV curve shift when one of substring cell is shaded and temperature rises on the module. Due to local shading or failure, the shaded cell short-circuit current become smaller than the rest of devices in the series string. Partially shaded cells are forced to pass a current higher than their generation capabilities, they become reverse biased, entering into the breakdown regime, and sink power instead of sourcing it. The shaded cell is strongly reverse-biased and dissipates the power produced by the unshaded cells.

Non-uniform distribution of current across the junction leads to Avalanche breakdown occurring, preferentially at localized regions. Intense local heating can produce very high temperatures (commonly known as a hot spot). If a temperature of around 150°C is reached, the lamination material becomes degraded and the module irreversibly deteriorated. Because of the localized nature, solar cells show large scattering in their reverse characteristics so that the module behavior under partial shading is not accurately predictable.

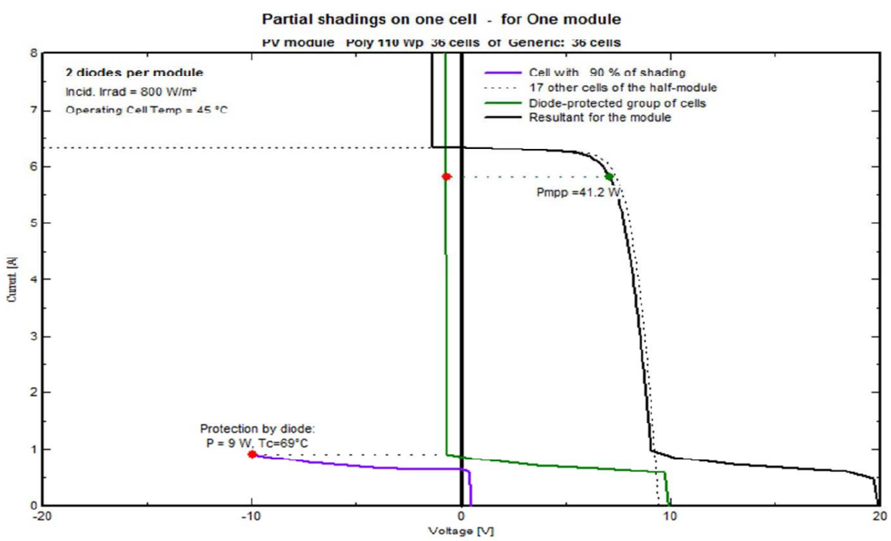

Figure 4.4 I-V Characteristics shift for one cell 90% shaded (with 2 BPD/ Module)

Figure 4.4 illustrates this behavior for a module protected by 2 bypass diodes in an 18-cell string with one cell shaded, so that it's short-circuit current becomes half of that of remaining devices. The curves show the 'diode protected' behavior of the module. It illustrates the operation of the bypass diodes. When the current forced through the shaded substring is such that the reverse bias equals the diode threshold voltage, the bypass diode sinks all necessary current to keep the string at this biasing point thus preventing the power dissipated in the shaded cell to increase. It is also important that the bypass diode leads to a significant increase of output of the module power and keep delivering the power generated by the unaffected groups.

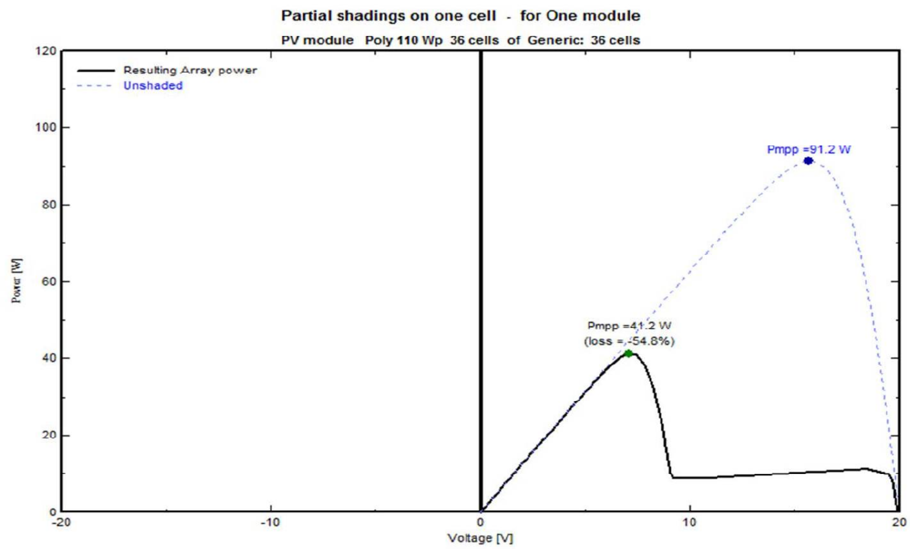

Figure 4.5 P-V Characteristics for unshaded and one cell 60% partially shaded module

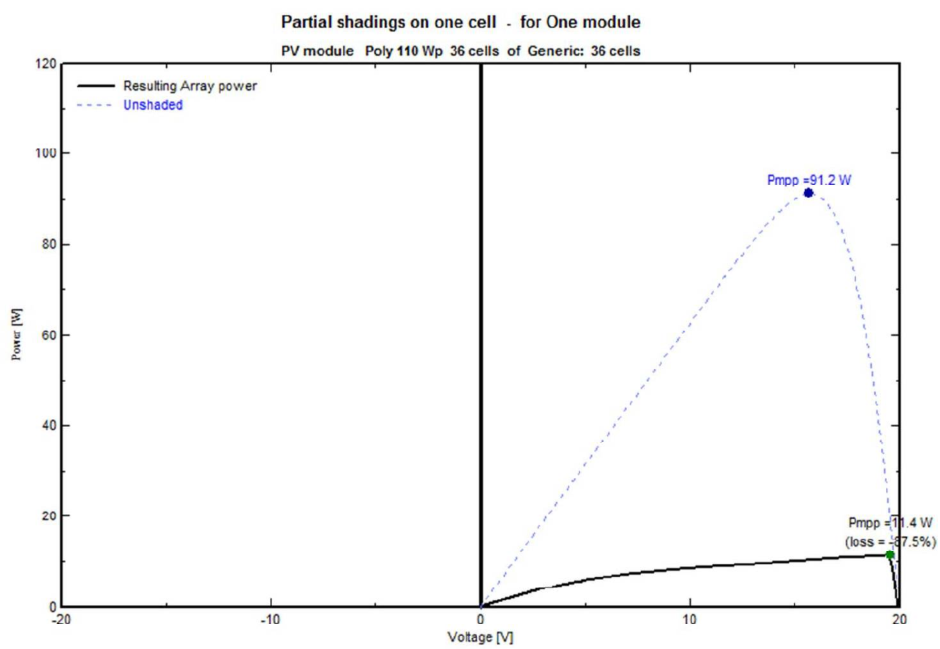

Figure 4.6 P-V Characteristics for unshaded and one cell 90% partially shaded module

Figure 4.5 & 4.6 depict the P-V characteristics of PV module in unshaded and partially shaded performance and the shift in P_{mpp} due to the shade percentage increase can also be observed. This effect, of course, severely degrades the efficiency of the module, but more important is the fact that it can get damaged, if unprotected.

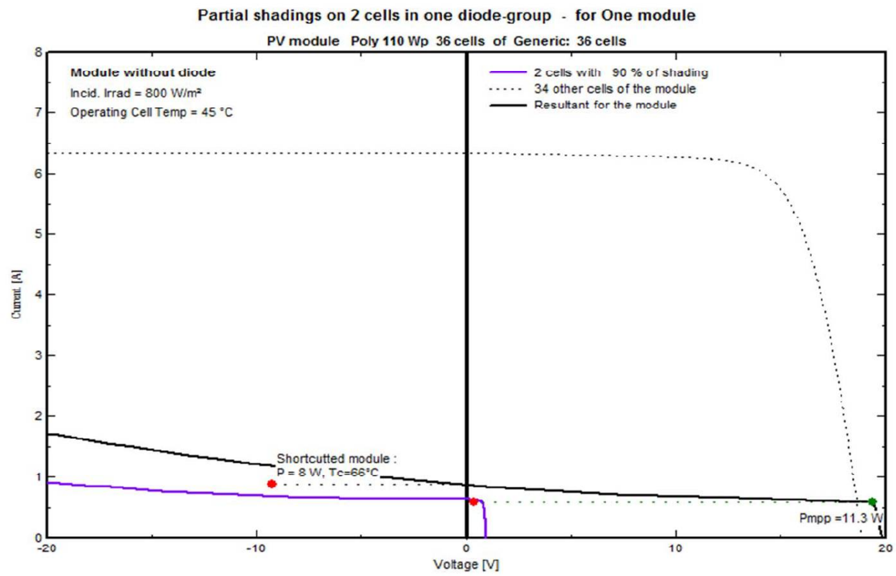

Figure 4.7 I-V Characteristics shift for two cells 90% shaded (without BPD)

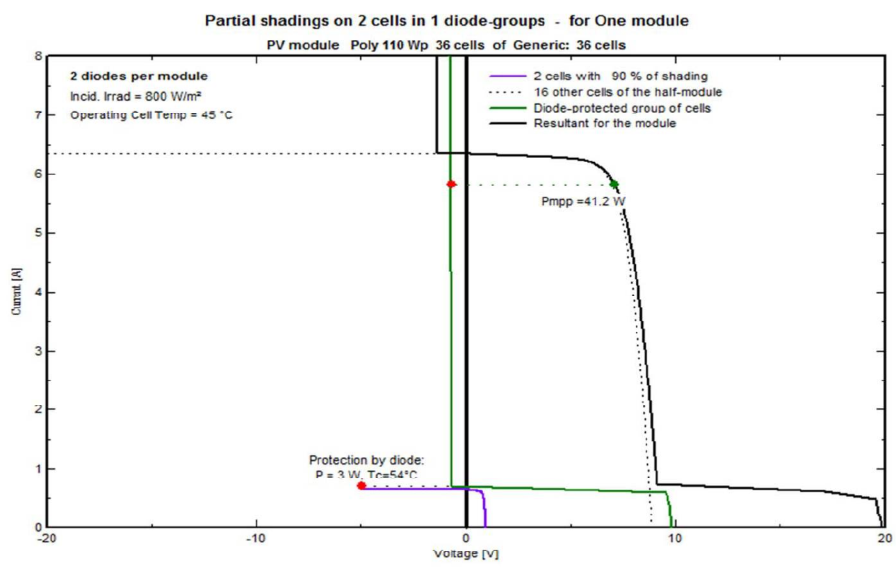

Figure 4.8 I-V Characteristics shift for two cell 90% shaded (with 2 BPD/ Module)

Figure 4.7 and 4.8 depict the I-V characteristics, when two cells are partially shaded without and with diode respectively which has similarity with current reduction with Figure 4.3 & 4.4.

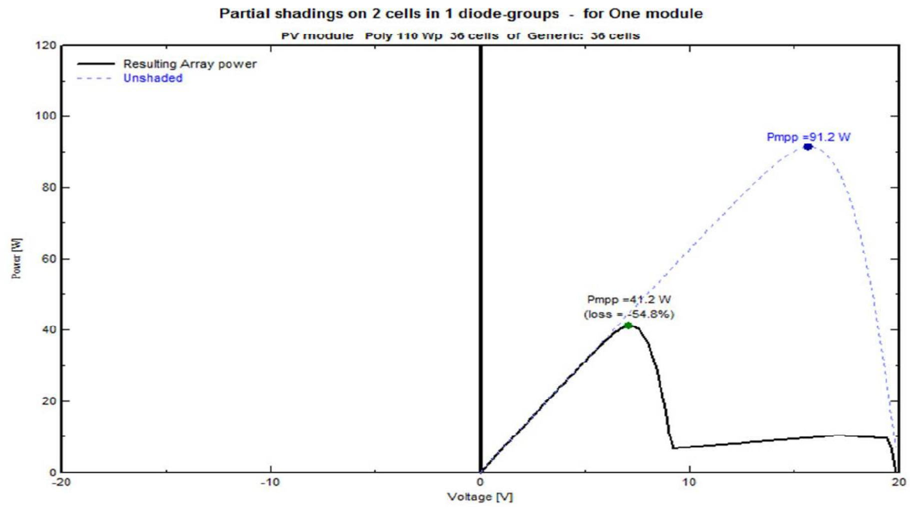

Figure 4.9 P-V Characteristics for unshaded and two cells 60% partially shaded module

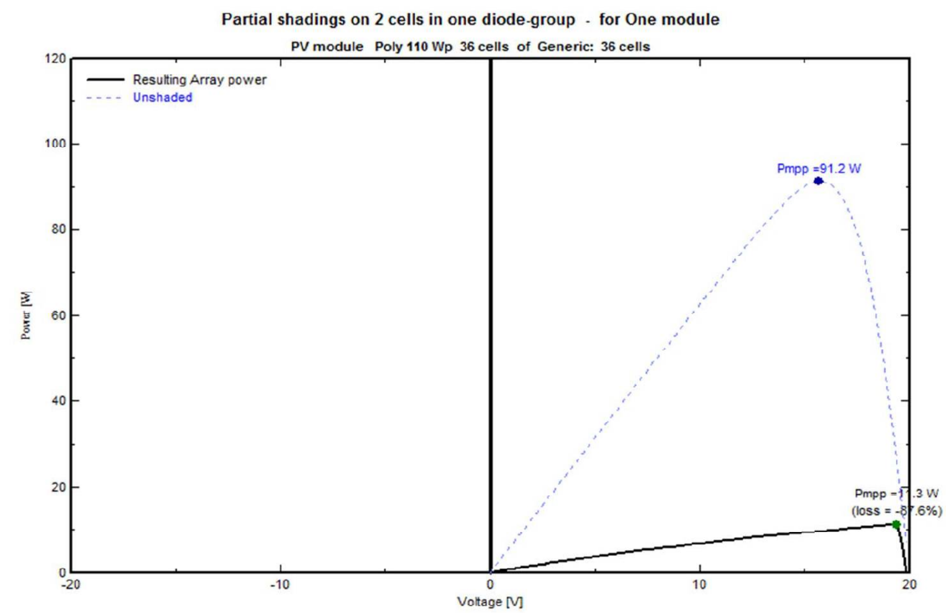

Figure 4.10 P-V Characteristics for unshaded and two cells 90% partially shaded module

Figure 4.9 and 4.10 depict the P-V characteristics when two cells are partially shaded in each substring which has similarity with Figure 4.5& 4.6 but the power loss is same with single cell shading.

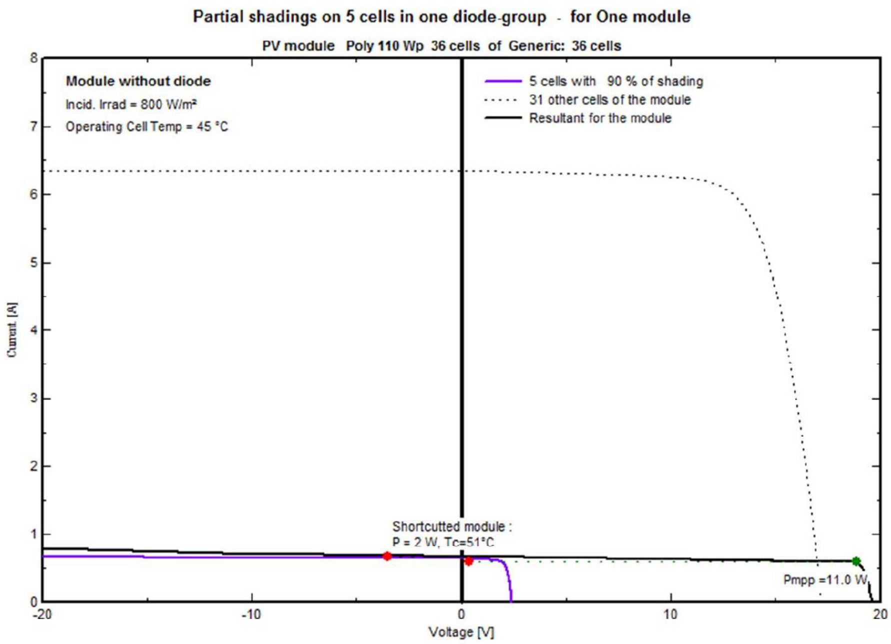

Figure 4.11 I-V Characteristics shift for five cells 90% shaded (without BPD)

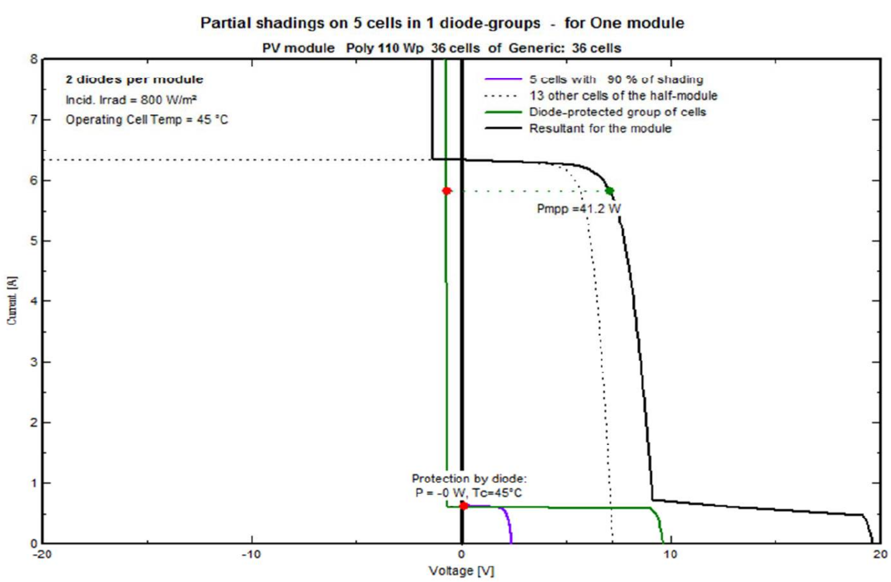

Figure 4.12 I-V Characteristics shift for five cell 90% shaded (with 2 BPD/ Module)

Figure 4.11 and 4.12 depict the I-V characteristics when two cells are partially shaded without and with diode respectively which has similarity with current reduction with Figure 4.3 & 4.4.

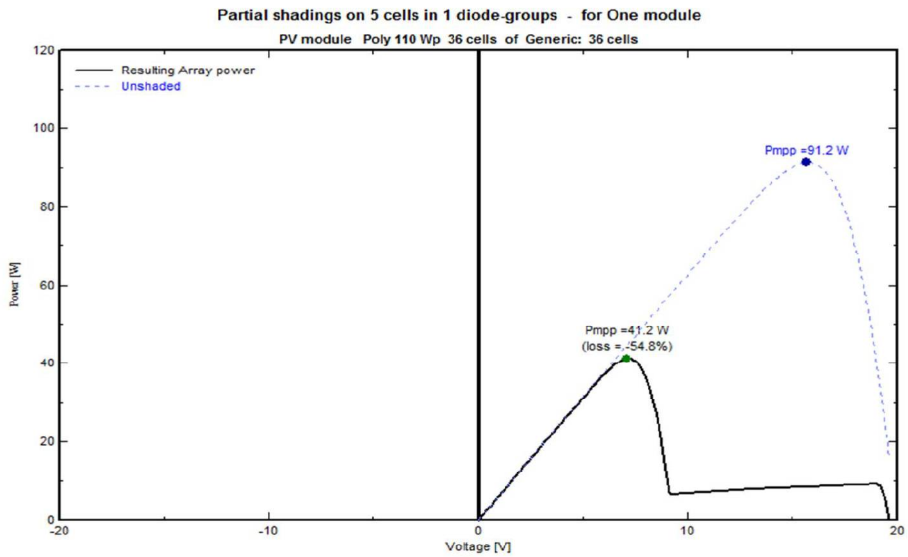

Figure 4.13 P-V Characteristics for unshaded and five cells 60% partially shaded module

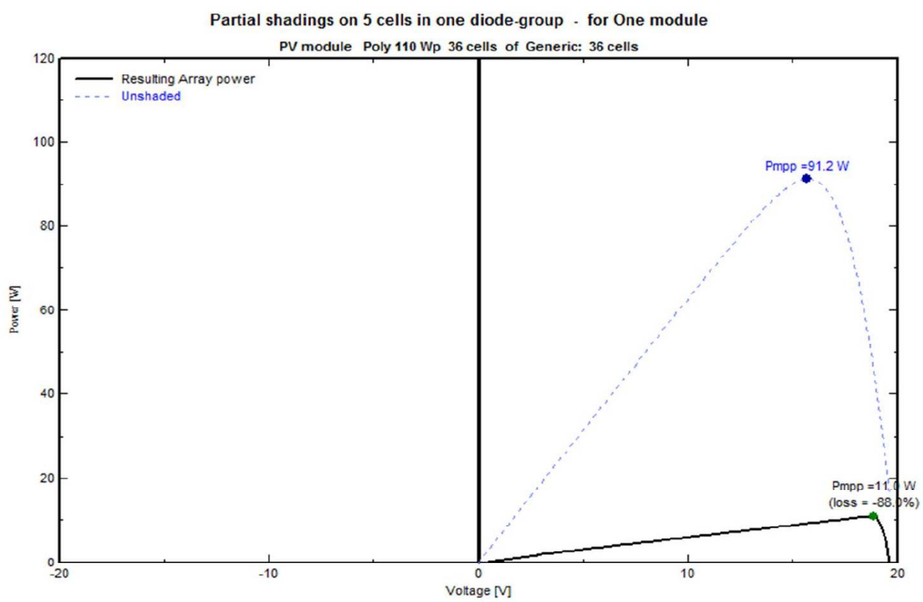

Figure 4.14 P-V Characteristics for unshaded and five cells 90% partially shaded module

Figure 4.13 and 4.14 depict the P-V characteristics when five cells are partially shaded in each substring which has similarity with Figure 4.5& 4.6 but the power loss is same with single cell shading.

4.3 MONO CRYSTALLINE PV MODULE (250 W_p) SIMULATION

The simulation of a mono-crystalline Si 250 Wp PV module with 60 cells begins with characterization study. Normal and shaded performance of I-V and P-V curves are simulated with variability of number of cells shade, percentage of shade, with/without presence of by-pass diodes (BPD) under incident irradiance of 800 Wm^{-2}. The temperature rises on the module cell are recorded for data analysis. The simulation figures are depicted in the Appendices of this thesis.

4.4 SUMMARY

Simulation study is the key prior to the empirical test and the environmental parameters aspects of the test site has been studied. The I-V and P-V curves of a PV module is characterized with, a 36 cells poly crystalline and a 60 cells mono crystalline PV modules which gives a basic understanding of the behavior under partially shaded operation. The hot-spot cause is studied through the bypass diode properties. This chapter gives the outsight for the experimentation and results chapter.