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OBSERVATION OF SOLAR PHOTOVOLTAIC ENERGY HARVESTING SYSTEM

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ABSTRACT:*All over the world, the growth in electric power demand has slowed down and dropped to 0.7% per year [1]. Capacity addition to the grid has kept up with the demand, but the sources of generation have varied over decades. This has given renewable energy sources a tremendous growth potential, and recent capacity additions have come mainly from natural gas and renewable. Among renewable, solar and wind power provide most of the growth [1]. The steady and rapid growth in solar photovoltaic installation across the world has been driven by many factors including renewable portfolio standards, decreasing costs of installations and incentives[1]–[3]. The increasing capacity addition of solar PV and installation of larger power stations has led to research and development in high-power converter topologies for PV applications. In this paper presenting the different observations of solar PV system and also observed the characteristics of voltage and current or voltage and power for different solar radiation and temperature respectively. In second observation we observed and analysis the performance of PV module in series or parallel connection with respect to I-V and V-Pcharacteristics. In third observation, studied the effect of shading on module output power. In fourth and fifth observation, to overcome the problem in shading module in output power by using the DC-to-DC converter and also observed the MPP by varying the duty cycle of converter. In sixth and seventh case, to observed the performance of SEPIC converter in open and closed loop system respectively and to overcome the problem of boost and Buck converter.*

INTRODUCTION

Solar energy is the raw material and main source for several applications of renewable energy systems; thus, knowledge about the intensity of solar irradiation is essential for efficiency of these systems. Electric energy sources capable of meeting the growing demands of society with minimal impacts to the environment and high efficiency have been object of research in the last decade. In this context, the conversion of sunlight into electricity through photovoltaic cells has become one of the most encouraged and used resources in the world. However, the most unpredictable factor, which hampers capturing solar irradiation, preventing a proper conversion of sunlight into electricity, is the presence of clouds in the sky.

LITURATURE REVIEW

SomasundaramEssakiappanet. al. [4] discussed megawatt-scale PV plant is divided into many zones, each comprising of two series-connected arrays. Each zone employs a medium-frequency transformer with three secondary's, which interfacewith the three phases of the medium voltage grid. An insulated-gate bipolar transistor full bridge inverter feeds the MF transformer. The voltages at the transformer secondary's are then converted to three-phase line frequency ac by three full-bridge ac–ac converters. Second line frequency harmonic power does not appear in the dc bus, thereby reducing the dc capacitor size. Cascading several such cells, a high-quality multilevel medium-voltage output is generated. A new control method is proposed for the cascaded multilevel converter during partial shading while minimizing the switch ratings. The proposed topology eliminates the need for line frequency transformer isolation and reduces the dc bus capacitor size, while improving the power factor and energy yield. Paper presents the analysis, design example, and operation of a 10-MW utility PV system with experimental results on a scaled-down laboratory prototype.

Nicolae-Cristianet. al. [5] introduces a reliability-oriented design tool for a new generation of grid-connected photovoltaic (PV) inverters. The proposed design tool consists of a real field mission profile (RFMP) model (for two operating regions: USA and Denmark), a PV panel model, a grid-connected PV inverter model, an electrothermal model, and the lifetime model of the power semiconductor devices. An accurate long-term simulation model able to consider the one-year RFMP (solar irradiance and ambient temperature) is developed.

Thus, the one-year estimation of the converter device thermal loading distribution is achieved and is further used as an input to the lifetime model. The proposed reliability-oriented design tool is used to study the impact of mission profile (MP) variation and device degradation (aging) in the PV inverter lifetime. The obtained results indicate that the MP of the field where the PV inverter is operating has an important impact (up to 70%) on the converter lifetime expectation, and it should be considered in the design stage to better optimize the converter design margin. In order to have correct lifetime estimation, it is crucial to consider also the device degradation feedback (in the simulation model), which has an impact of 20–30% on the precision of the lifetime estimation for the studied case.

Abhijit V. Padgavhankar [6] solar photovoltaic system convergence time is reduced using maximum power point tracking algorithm which responds faster to the atmospheric changes over a conventional algorithm with minimum ripple content in the output. Digital controller is used to control the dc-dc boost power converter and dc-ac inverter using efficient soft switching pulses. Voltage sensor is used to vary width of the pulse to maintain the boost converter output constant level. Using current sensor frequency of the generated pulse is varied so ripple contents of the output are reduced to improve the power quality. MOSFET single phase H-bridge inverter is used to convert constant solar power into ac signal with the minimum ripple in the output and power losses. Efficient sinusoidal pulse width modulation technique is used to reduce the switching losses with the help of digital controller. For the proposed system validation Proteus 8 simulation and implemented hardware results are presented. The system has minimum switching losses, faster convergence time and high power quality.

Mr.K.Natarajan1 et. al. [7] presents the design of a Single Ended Primary Inductor Converter (SEPIC) for solar PV system. SEPIC acts like a buck-boost DC-DC converter and it allows a range of DC voltage adjust to maintain a constant output voltage. Maximum Power Point Tracking (MPPT) technique should be used to track the maximum power point continuously which depends on panel's irradiance conditions in PV solar system. The Maximum power point has been achieved by adjusting the switching frequency of the converter. The efficiency of the converter is improved by the coupled inductor because it needs only lesser amount of magnetic core. The SEPIC converter and their various control strategies has been discussed and simulated using Simulink/MATLAB software.

Observation 1: Observation of I-V & P-V characteristics of PV module with varying radiation andtemperature level.

In this observation I show the relation between current and voltage or power and voltage. So voltage is one of the most important parameter of solar PV system. PV module is characterized by its I-V and P-V characterized curves. As shown in figure1(a) & figure 1(b) .

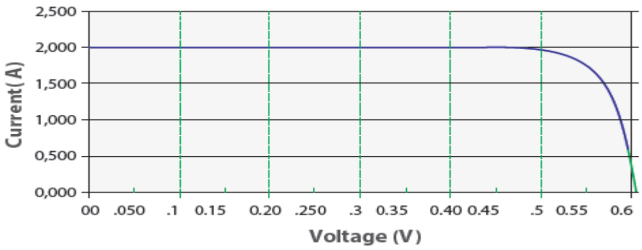


Figure 1: (a) Ideal I-V characteristics of PV module

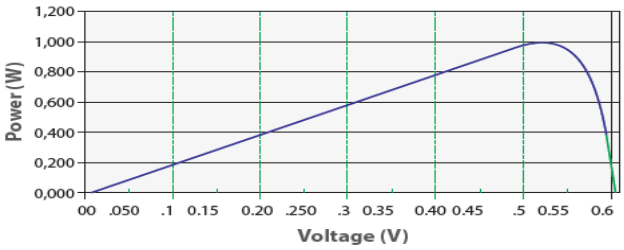


Figure 1: (b). Ideal P-V characteristics of PV module

In characteristics maximum current at zero voltage is the short circuit current (Isc)which can be measured by shorting the PV module and maximum voltage at zero current is the open circuit voltage(Voc). In PV curve the maximum power achieved only at a single point which is called MPP (maximum power point) and the voltage corresponding to this point are referred as Vmp& Imp. On increasing the temperature ,Voc of module decreases as shown in fig (1.2) which Isc remain the same which in turn reduces the power. For most crystalline silicon solar cells module the reduction is about 0.50%, /^{0}c.

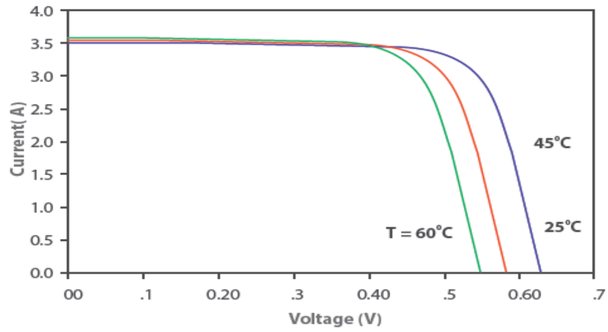


Figure 2: Ideal variation in Voc with change in temperature

On changing the solar insolation Isc of the module increases ,while the Voc increases very slightly shown in fig (1.3)

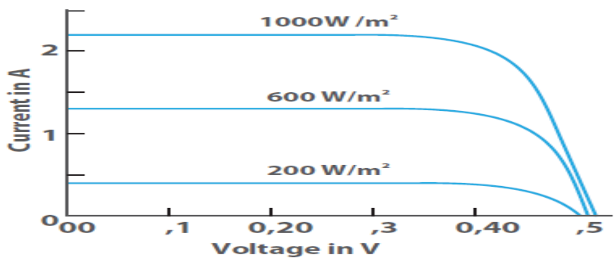


Figure 3:Ideal variation in I-V characteristics with insolation.

Fill factor (FF) is essentially a measures of quality of the solar cell.it is the ratio of the actul achievable maximum power to the theoretical maximum power (Pt) that would be achieved with open circuit voltage and short circuit together .FF can also be interpreted graphically as the ratio of the rectangular areas depicted in fig (1.4). a large fill factor is desirable ,& corresponding to an I-V sweep that is more square-like typical fill factor range from 0.5 to 0.82 fill factor is also often represented as per percentage.

$$F.F = \frac{Pmax}{Pt} = \frac{Imp.Vmp}{Isc.Voc}$$

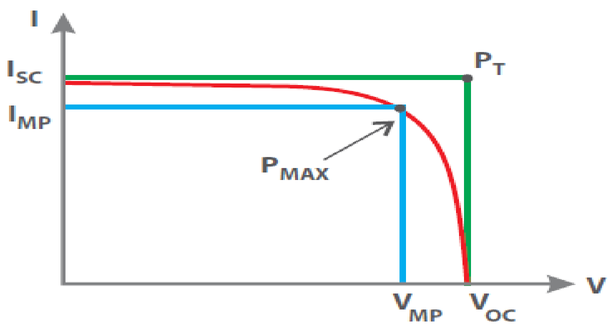


Figure 4: Ideal graphical interpretation of the fill factor (FF)

Analysis set up :

The circuit diagram to evaluator I-V & P-V characteristics of a module is shown in fig (1.5)

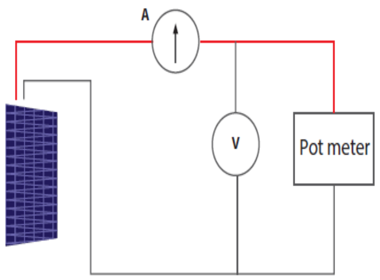


Figure 5: Circuit diagram for evaluation of I–V &P-V characteristics

For PV system which included PV module & a variable resistor (pot meter) with ammeter & voltmeter for measurement .pot meter in this circuit work as variable load for the module. When load on the module is varied by pot meter the current & voltage of the module gets changed which shift the operating point on I-V & P-V characteristics.

Table 1:- I-V characteristics of PV module with 5.0 Radiation

Set.1					
Sr. No	**Radiation (w/m^2)**	**Temperature**	**V**	**I**	**P**
1			Voc	0	
2	5.0	31.4	17.2	0.07	1.204
3	5.0	31.8	18.1	0.12	2.172
4	5.0	32.4	18.6	0.18	3.528
5	5.0	33.6	18.9	0.20	3.98
6			0	Isc	

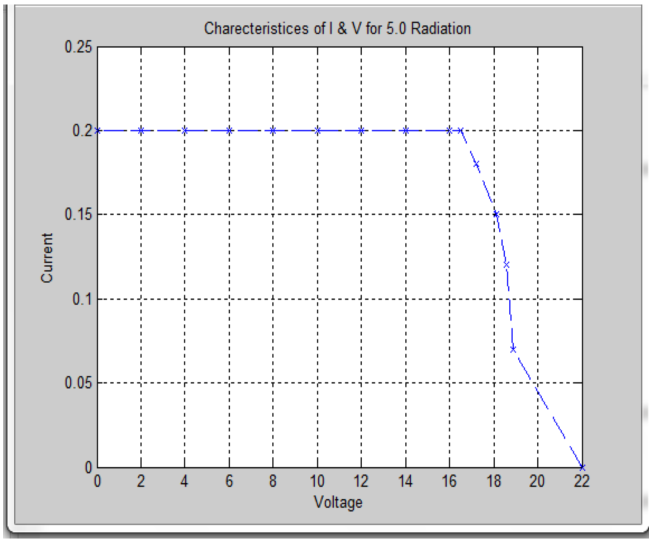


Figure 6: (a) Characteristics of I& V for 5.0 Radiation

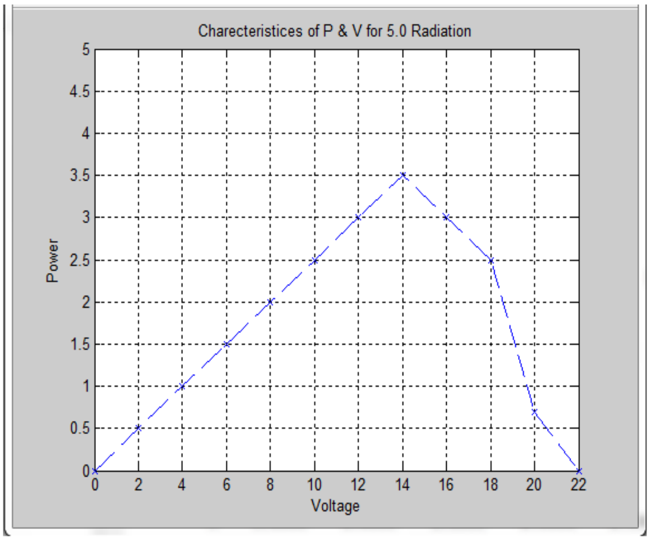
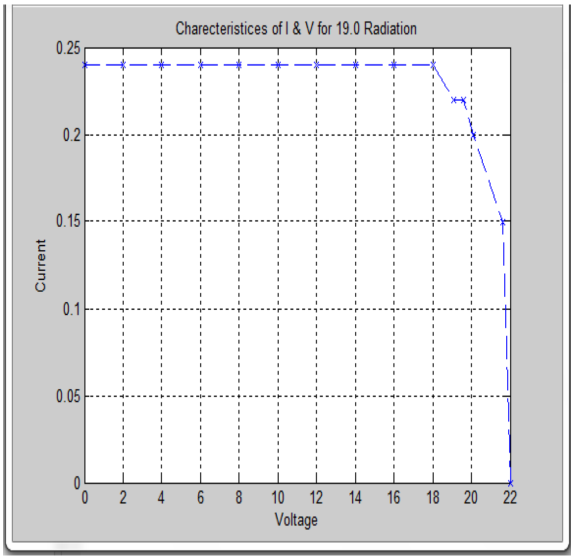


Figure 6: (b) Characteristics of P & V for 5.0 Radiation

Table 2: I-V characteristics of PV module with 9.0 Radiation

Set.2					
Sr No	**Radiation (w/m²)**	**Temperature**	**V**	**I**	**P**
			Voc	0	
1	9.0	34.8	19.1	0.12	2.292
2	9.0	35.9	19.6	0.15	2.94
3	9.0	37.1	20.1	0.19	3.819
4	9.0	38.4	21.6	0.22	4.752
			0	Isc	



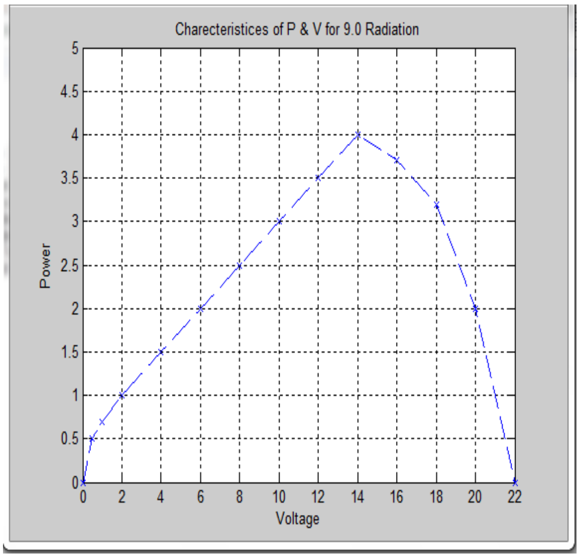


Figure 7: (a) Characteristics of I& V for 9.0 Radiation **Figure 7: (b) Characteristics of I& V for 9.0 Radiation**

These are 2setfor different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Observation 2: I-V &P-V Characteristics of series and parallel combination of PV module

PV module is characterized by its I-V characteristics. At a particular level of solar insolation and temperature it will show a unique I-V and P-V characteristics, these characteristics can be altered as per requirement by connecting both modules in series or parallel to get higher voltage or higher current as shown in figure 9(a), figure 9 (b), figure 10 (a) and figure 10 (b) respectively.

On increasing the temperature,Voc of modules decreases while Iscremains same which in turn reduces the power. Therefore, if modules are connected in series then power reduction is twice when connected in parallel.

Analysis set up :

The circuit diagram to evaluate I-V &P-V characteristics of module connected in series and parallel are shown in figure 8 (a) and figure 8 (b) respectively. from a PV system with modules in either series or parallel and a variable resistor with ammeter and voltmeter for measurement .modules in series or parallel are connected to variable load .the effect of load change on output voltage and current of the modules connected in series or parallel can be seen by varying load resistance.

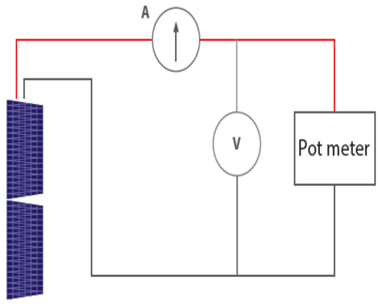


Figure 8 (a) circuit diagram for evaluation of I-V & P-V characteristics of series connected modules

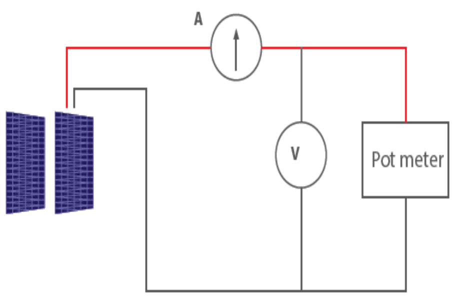


Figure 8 (b) circuit diagram for evaluation of I-V & P-V characteristics of parallel connected modules.

Table 6:I-V AND P-V characteristics of PV modules in series with 4.0 radiation

Set1					
Sr No	**Radiation**	**Temperature**	**V**	**I**	**P**
1			Voc	0	
2	4.0	33.2	1.18	0.6	0.708
3	4.0	32.7	5.7	0.6	3.42
4	4.0	32.6	10.7	0.6	6.42
5	4.0	32.5	14.6	0.6	8.76
6			0	Isc	

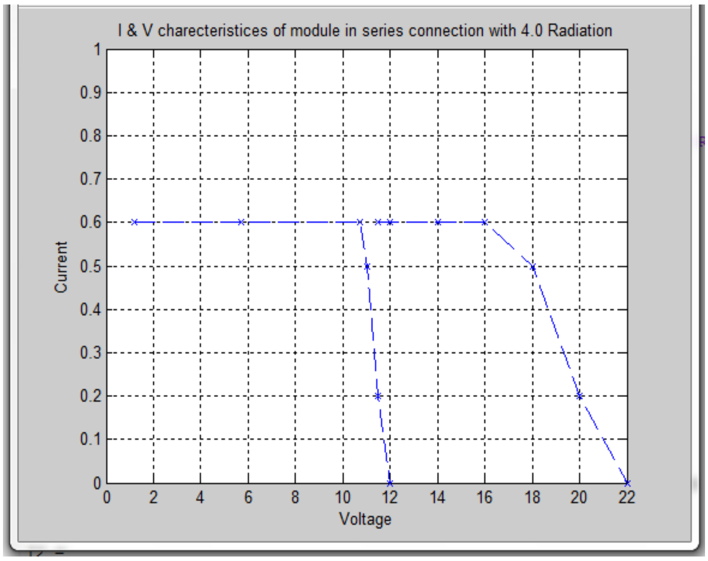


Figure 9 (a)I-V characteristics of series connected modules with 4.0 Radiation

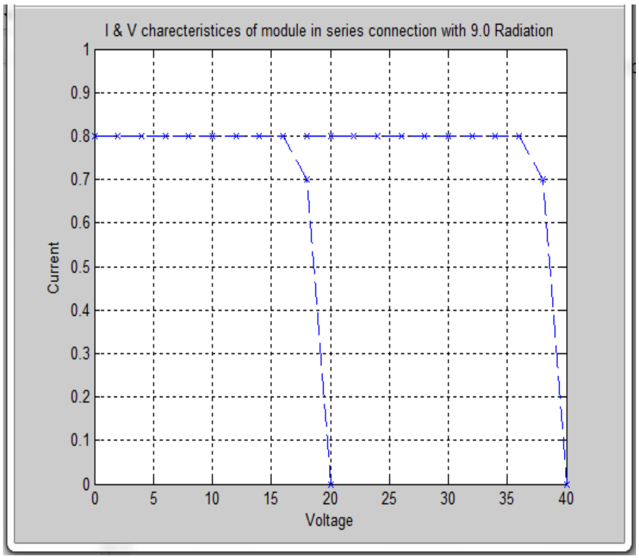


Figure 9: (b) I & V Characteristics of module in series connection with 9.0 Radiation

Table 7:I-V AND P-V characteristics of PV modules in series with 9.0 radiation

Set2					
Sr No	**Radiation**	**Temperature**	**V**	**I**	**P**
1			Voc	0	
2	9.0	32.5	39.1	0.17	6.647
3	9.0	38.4	38.4	0.22	8.448
4	9.0	37.1	37.1	0.35	12.985
5	9.0	37.2	37.2	0.57	21.204
6			0	Isc	

These 2set are for different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Table8: I-V AND P-V characteristics of PV modules in parallel with 13.0 radiation

Set1					
Sr No	**Radiation**	**Temperature**	**V**	**I**	**P**
1			Voc	0	
2	13.0	34.8	19.5	0.08	1.56
3	13.0	35.5	19.4	0.12	2.328
4	13.0	35.8	19.3	0.18	3.474
5	13.0	36.1	18.6	0.47	8.742
6			0	Isc	

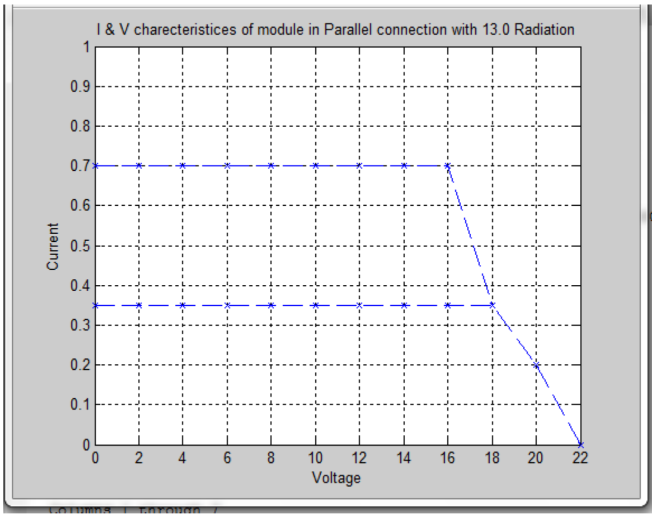


Figure 10: (a) I& V Characteristics of module in parallel connection with 13.0 Radiation

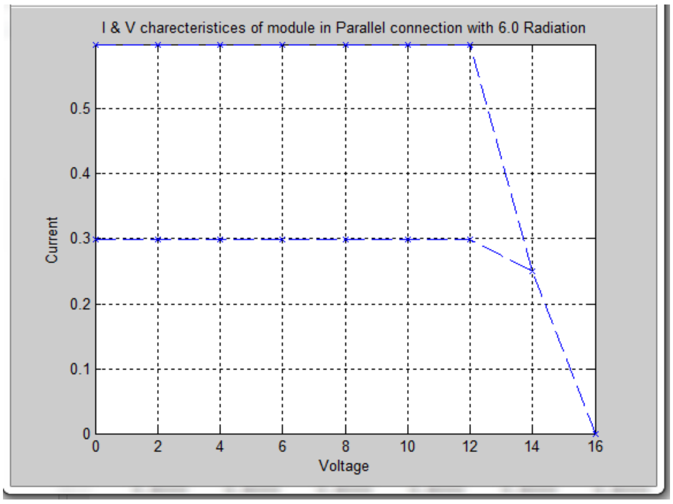


Figure 10: (b) I & V Characteristics of module in parallel connection with 6.0 Radiation

Table9: I-V AND P-V characteristics of PV modules in parallel with 6.0 radiation

Set2					
Sr o	**Radiation**	**Temperature**	**V**	**I**	**P**
1			Voc	0	
2	6.0	36.5	13.4	0.05	0.67
3	6.0	36.4	12.7	0.06	0.762
4	6.0	36.3	9.8	0.12	1.176
5	6.0	35.9	7.2	0.15	1.08
6			0	Isc	

These two set are for different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Observation 3 : observation of the effect of shading on module output power

There are 36 solar cells in module which I observed .these 36 solar cell are in series, which make the module as series connected solar cells.These cells are in series without bypass diode so shading of one cell will be sufficient to reduce the power to zero.This arrangement gives zero power if the entire row of cells gets shaded.

Analysis set up:

There are shading elements of different sizes(single cell, two cell, four cell and 9 cells of module) for covering the solar cell(or cells) of module completely. for executing this experiment, put one of these shading elements on the solar cells. after making the cells shaded by different sizes of shading elements, note down the readings of current and voltage.

Table 10: table for evaluating the effect of shading on cells

Sr.No	Types of shading element	V (volts)	I (ampere)	P (power)
1	No cell is shaded	15.9	0.18	2.862
2	Single cell is shaded	13.1	0.14	1.83
3	Two cells	12.0	0.12	1.44
4	four cells	9.2	0.10	0.92
5	Nine cells	6.8	0.06	0.408

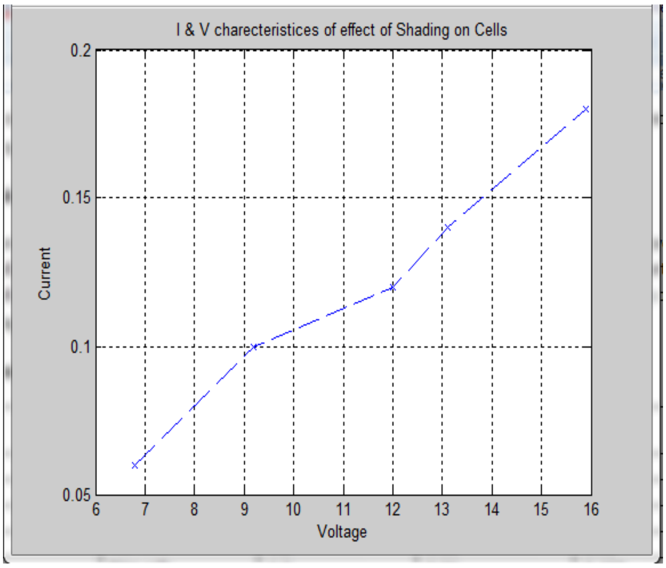


Figure 11: (a) I & V Characteristics of effect of Shading on Cell

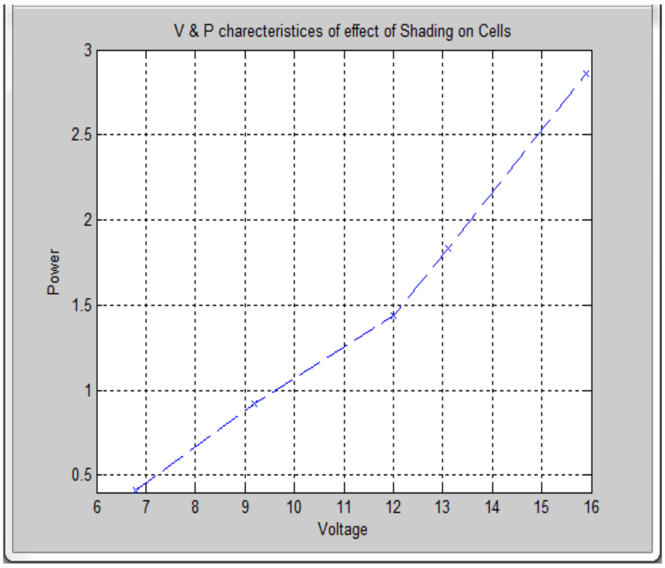


Figure 11: (b) I & V Characteristics of effect of Shading on Cell

Observation 4: observation to find the MPP manually by varying the resistive load across the PV panel

PV module is characterized by its I-V and P-V characteristics. At a particular solar insolation and temperature module characteristics curves shown in figure 12 (a) and figure 12 (b).

In these curves maximum current at the zero voltage is called short circuit current (Isc) and the maximum voltage is known as open circuit voltage (Voc). In P-V curve the maximum power is achieved only at single point which is called MPP (maximum power point) and the voltage & current corresponding to this point are referred as Vm&Im .this single point is corresponds to a load resistance, known as critical load resistance.

Analysis set up

There is a PV system which includes PV module and a potential meter with ammeter and voltmeter for measurement .potential meter in this circuit works as a variable load which is connected to the module directly so it change the current and voltage of the module as it is rotated.one can use digital meters as well as data logger / plotter for taking readings. One can take data from logger/plotter by connecting the logger plotter box with module output .values of current and voltage can be taken from the digital meters and data logger, and then I-V curves can be plotted at different radiation and temperature levels. One can also use real time plotter which will plot the curves of I-V &P-V at different radiation and temperature levels.

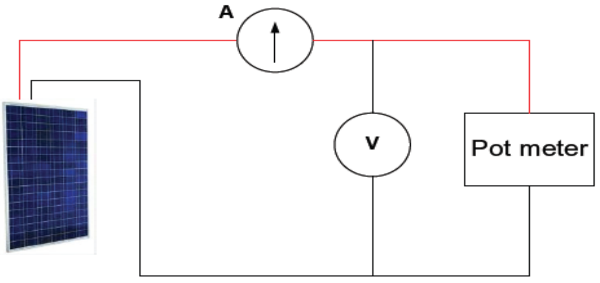


Figure 12: circuit diagram of PV system.

Table 11: For the fixed radiation and temperature I note remaining reading for different values of load resistance R.

Sr. No	V(Volts)	I(ampere)	R(ohms)	P(watt)
1	17.2	0.07	1.1	1.204
2	18.1	0.12	1.90	2.172
3	18.6	0.18	2.98	3.528
4	18.9	0.20	3.75	3.98

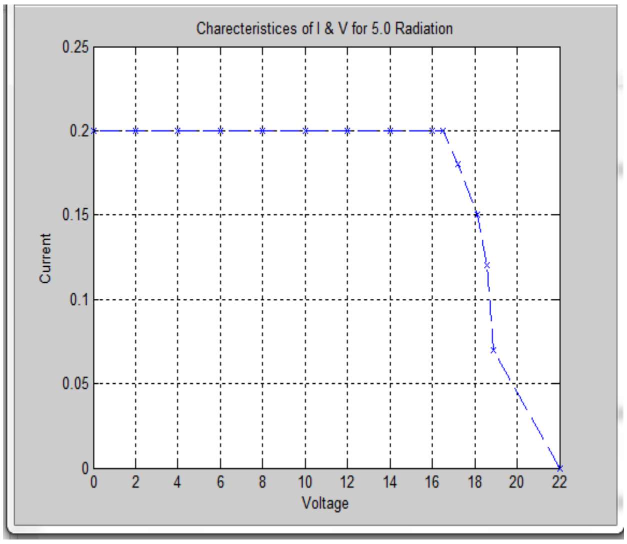


Figure 13 (a) I & V Characteristics for 5.0 Radiation

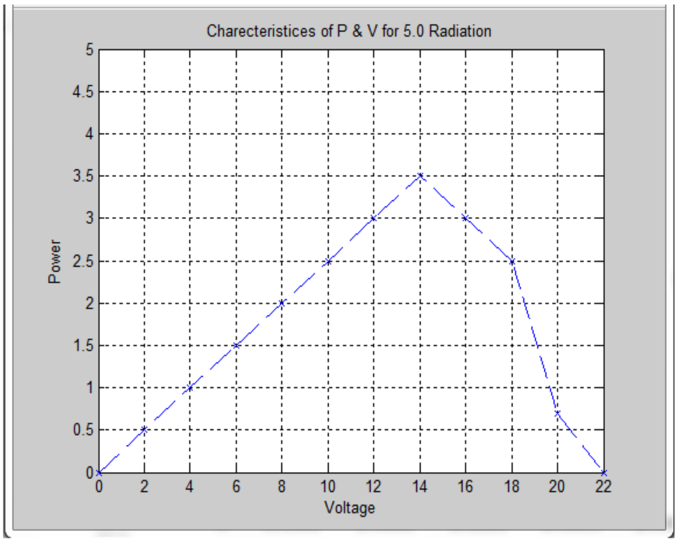


Figure 13 (b) P& V Characteristics for 5.0 Radiation

Observation 5: observation to find t6e MPP by varying the duty cycle of DC to DC converter.

PV module is characterized by its I-V and P-V characteristics. At a particular solar insolation and temperature it will shows a unique I-V and P-V curve. These curves can be altered by connecting these modules in series and parallel combination in characteristics are done for increasing current or voltage from PV array. Different sets of current and voltage can be obtained by changing the impendence across the PV module (or PV array). These sets can also be obtained by varying the duty cycle of DC to DC converter across the PV panel.

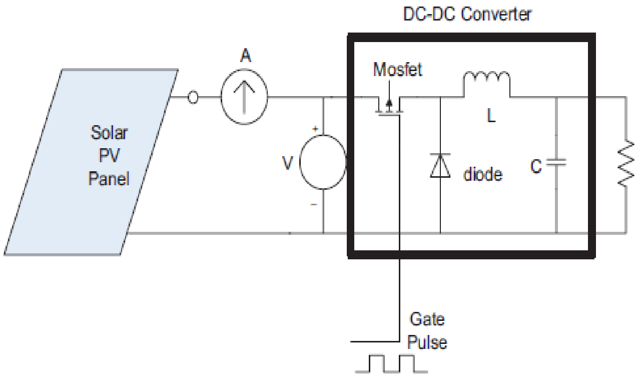


Figure 14: Circuit diagram of buck type DC-DC converter

Assume the efficiency of DC-DC converter to be 100%.

Duty cycle, $D = \frac{Vl}{Vp}$

$Zin = \frac{Zo}{D^2}$

Here, Zo = output impendence = Rl
Zin = input impedance of DC-DC converter as seen from converter input terminals.
Vp&Vl are panel voltage and load voltage respectively.

Analysis set up:

There is a PV system which includes PV module and a potential meter with ammeter and voltmeter for measurement. Potential meter in this circuit work as a variable load which is connected to the module directly so it forces to change the current and voltage of the module as it is rotated. DC to DC converter has an option of automatic and manual firing of gate pulse so it can be work either according to default gate firing or manual firing by external pulse generator. This experiment will be executed by taking the converter in manual mode so that duty cycle can be change by varying the gate pulse width (with the help of PWM generator). One can use digital meters as well as data logger/plotter for taking readings. One can take data from Logger/Plotter by connecting the Logger Plotter Box with module output. Values of current and voltages can be taken from the digital meters and data logger, and then I-V curve can be plotted at different radiation and temperature levels.

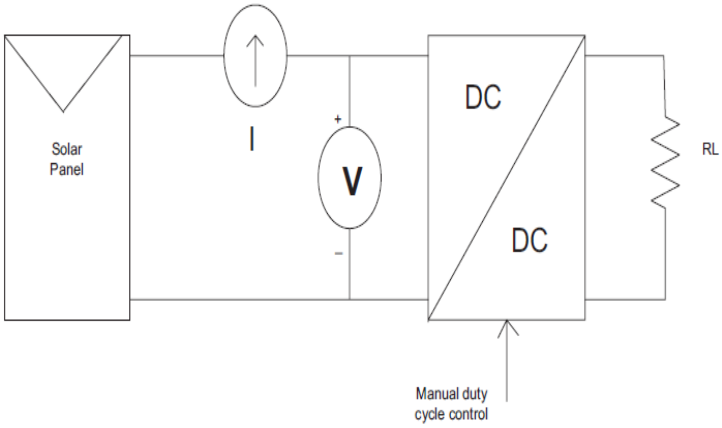


Figure 15: Experimental set-up for drawing I-V characteristics with the help of DC-DC converter

Table 12: Set 1 (for a certain value of 4.0 Radiation)

Sr. No	V_{in}	V_{out}	I_{out}	D
1	10	8.59	0.71	44.44%
2	11	6.75	0.56	30.86%
3	12	4.56	0.38	19.75%

Table 13: Set 2 (for a certain value of 9.0 Radiation)

Sr. No	V_{in}	V_{out}	I_{out}	D
1	10	9.95	0.78	45.59%
2	11	7.57	0.67	32.89%
3	12	5.68	0.44	21.79%

Observation6: SEPIC CONVERTER in open loop system

The SEPIC converter (Single Ended Primary Inductance Converter) is a configuration where the voltage output can be above or below the input voltage.

In fact in this particular design both Boost and Buck converter do coexist.If the duty factor is less than 50% then the circuit will behave as a buck converter.It will work as a boost converter if otherwise the duty factor is above to 50%.With the shown component values the converter works by ensuring a continuous current through the inductors, for this reason it's known as continuous mode.By reducing the inductor value the converter will move in the discontinuous mode.

The voltage output may be approximated as: Vout = (Vin*D)/(1-D) where:

D = T1/T (duty factor)

T = PWM period

T1= OFF time.

In the example for T=20us and T1=6.3us (D=31%) we have Vout is about 5V and the circuit behaving like a buck converter.

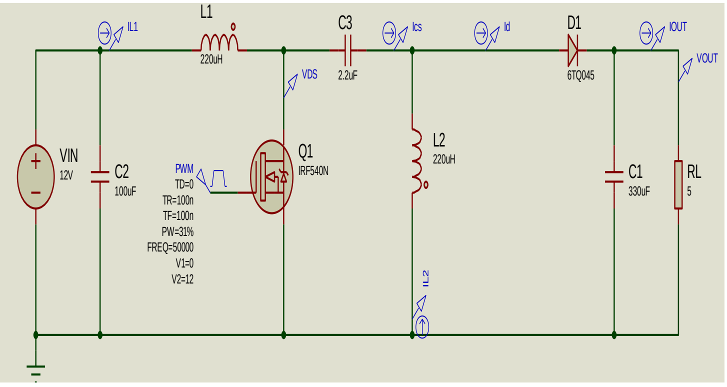


Figure 16:open loop SEPIC Converter

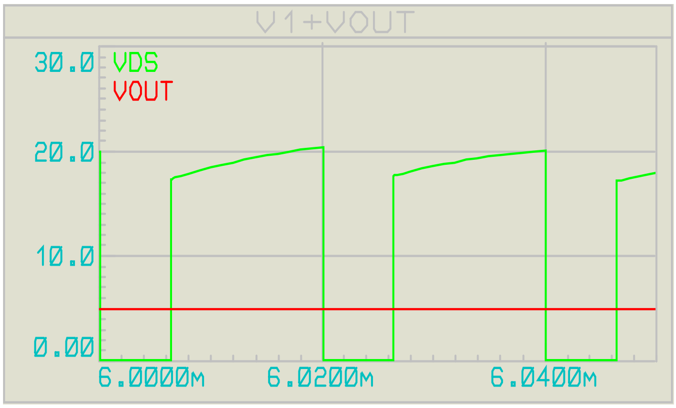


Figure 17: Waveform of V_{ds} and V_{out} of SEPIC converter

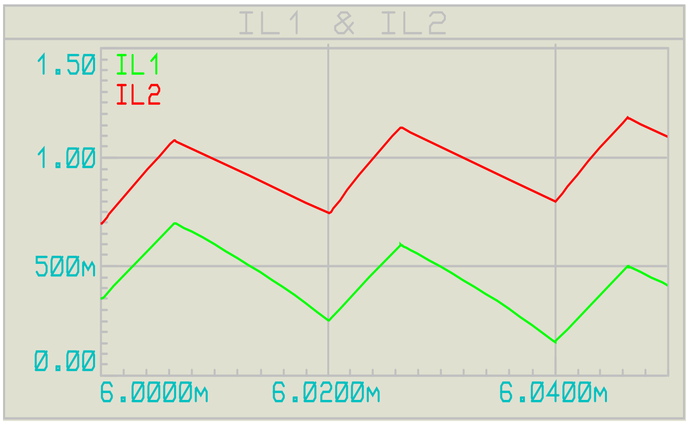


Figure 18: Waveform of IL1 and IL2 of SEPIC converter

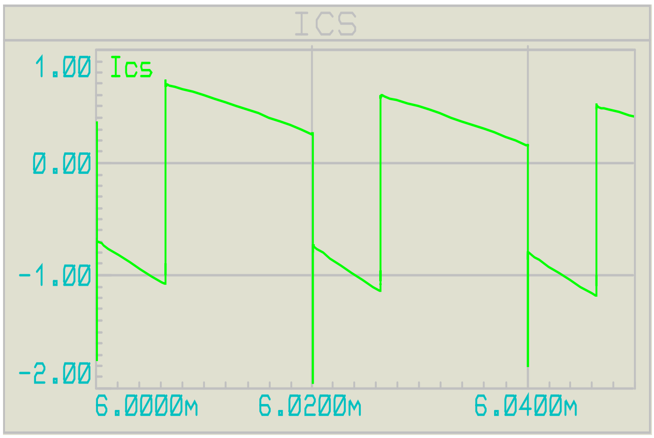


Figure 19: Waveform of $I_{cs}$of SEPIC converter

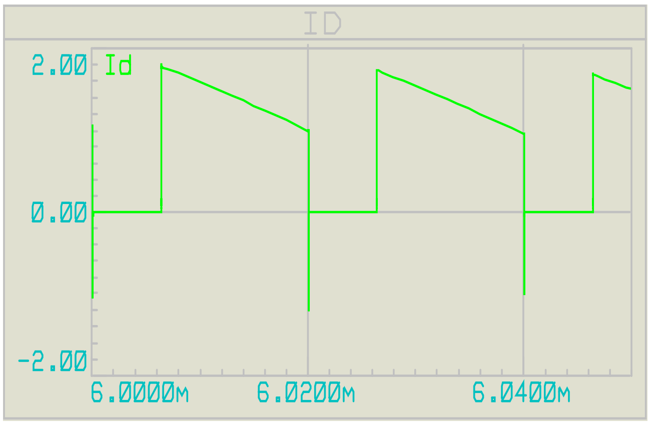


Figure 20: Waveform of Id of SEPIC converter

CONCLUSION

World has unique opportunity for energy efficiency implementation as well as renewable energy deployment. In this paper presenting the different observationsof solar PV system and also observed the characteristics of voltage and current or voltage and power for different solar radiation and temperature respectively. In second observation, we observed and analysis the performance of PV module in series or parallel connection with respect to I-V and V-P characteristics. In third observation, studied the effect of shading on module output power. In fourth and fifth observation, to overcome the problem in shading module in output power by using the DC-to-DC converter and also observed the MPP by varying the duty cycle of converter. In this paper, a digitally controlled SEPIC converter for solar PV with voltage and current sensing is presented. Maximum power point is estimated by sensing voltage and current which varies the duty cycle and frequency respectively of the pulse to minimize the power loss caused by switching losses and hence improvement in overall performance of the system. The overall observation shows that if input voltage of PV module has been changed due to environmental changes so there is no changes in Vout and Iout because of closed loop SEPIC converter.

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