ECE 513 ENERGY SYSTEMS

FINAL PROJECT

Section 1:

Location:

To design a PV panel circuit model, one of the most important criteria is to be considered is the temperature of the of the location. The given location is Albany, New York, in fig.1 it represents the data of the temperature yearly.

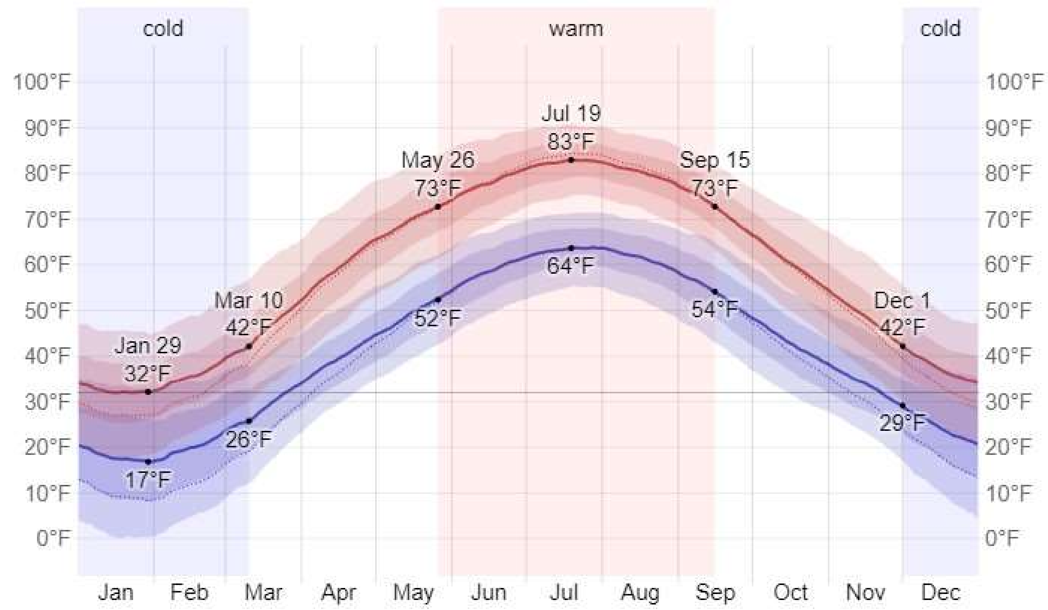


Fig 1. Expected Temperatures of Albany in the year 2024

Source: https://weatherspark.com/y/24883/Average-Weather-in-Albany-New-York-United-States-Year-Round

From the data in Fig 1., the lowest temperature of 17 F which is -8.33 ℃ and the highest is 83 F which is 28.33℃.

Let's take the absolute values of the temperatures now with the lowest are - 8℃ and the highest as 28℃.

Calculation of Open Circuit voltage at lowest temperature -8℃:

The PV panel will get the highest voltage at the lowest temperature. By using the datasheets of the PV panels provided, I am using "NES144/525- 530 W F 35mm MBB Half-cell Mono solar cell ".

Electrical Characteristics				
STC	NES144-7-525M	NES144-7-530M	NES144-7-535M	NES144-7-540M
Maximum Power(Pmax)	525W	530W	535W	540W
Optimum Operating Voltage(Vmp)	41.15V	41.31V	41.47V	41.64V
Optimum Operating Current(Imp)	12.76A	12.83A	12.90A	12.97A
Open Circuit Voltage(Voc)	49.15V	49.30V	49.45V	49.60V
Short Circuit Current(Isc)	13.65A	13.72A	13.79A	13.86A
Module Efficiency	20.31%	20.51%	20.70%	20.90%
Operating Module Temperature	-40℃ to +85℃			
Maximum System Voltage	1500V DC (IEC)			
Power Tolerance	0~+5W			
STC	Irradiance 1000 W/m², module temperature 25℃, AM=1.5; Best in Class AA			

Temperature Characteristics	
NOCT	45±2℃
Temperature Coefficient of Pmax	-0.350%/℃
Temperature Coefficient of Voc	-0.275%/℃
Temperature Coefficient of Isc	0.045%/℃

Fig.2 Datasheet of NES144/525- 530 W F 35mm MBB Half-cell Mono solar cell from Zhejiang JEC energy technology

The following is the data of NES144-7-530M from the datasheet:

STC= 25℃ and 1000 W/m^2

Open circuit voltage, Voc= 49.30V

Short circuit current, Isc= 13.72 A

Temp coefficient at Voc= -0.275 %/ C

Temp coefficient at Isc= 0.045%/ C

NOCT= 45±2 ℃

Now the Open circuit voltage at -8℃ is given by

Voc =(Voc (at 25℃)) * (1+(Min.temp-25) * temperature coefficient(Voc)
= 49.30 * { 1+ [(-8-25) * (-0.00275)] } = 53.77 V

<u>2) Calculation of the maximum Power Voltage VMPP at highest temperature 28℃:</u>

VMPP (28℃) =((Voc (at 25℃)) *(1+(Max.temp-25) * temperature coefficient (Voc)

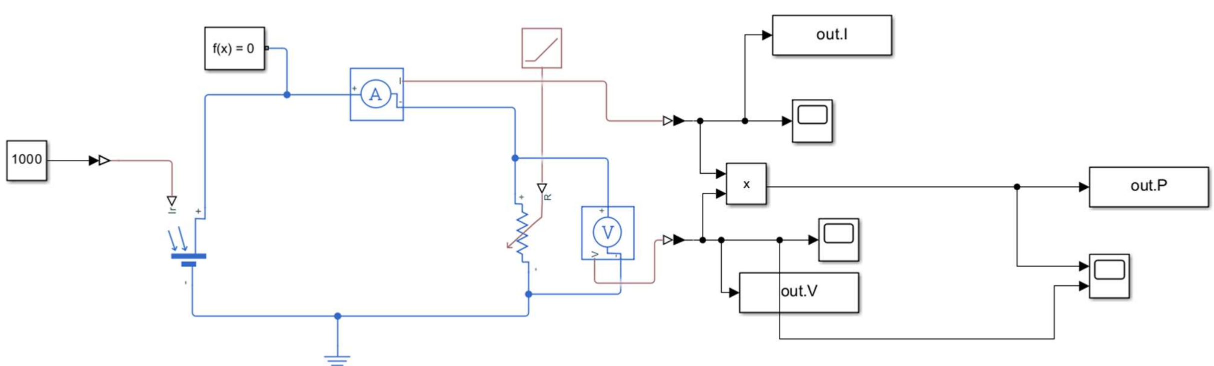
VMPP (28℃) =49.30 * {1+ [(28-25) * (-0.00275)] } = 48.89 V

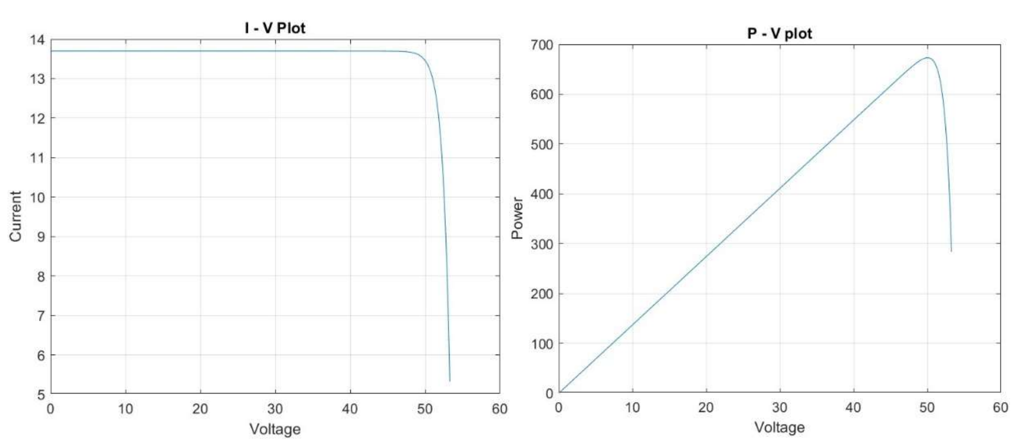
<u>3) Calculation of the maximum Power Current IMPP at 28</u>℃:

Impp (28℃)= Isc(at 25) *(1+ ((Max temp - 25) * (temperature coefficient (Isc))))
= 13.72*{ 1+ [(28 - 25)*(-0.00045)] }= 13.70 A

<u>4) Maximum Power at 28℃:</u>

Pmpp= Vmpp * Impp= 48.89 * 13.70 = 669.793 W= 670W





<u>Fig. 3 I- V, P- V plots MATLAB Simulation of PV panel with 144 cells at 1000 W/m^2 (24 series & 6 Parallel Strings)</u>

Section 2:

Specification	Value
Rated power	1 MW
Maximum allowable dc voltage	1500V
Location	Albany, NY

Determining total number of Panels required for 1 MW power:

The rated power is 1MW, each panel generates 670 W.

Total number of panels required = $\frac{1,000,000}{670}$ = 1492.79(rounding up) = 1493 panels

Determining how many series modules are required:

Given that the maximum voltage limit is 1500 V. At coldest temperature there will be high voltage.

Now based on the above PV panel Designed with a Voc of 53.77 V, we need to add the designed PV panel in series so that it will not cross the maximum limit.

So, No.of series strings required= 1500/ 53.77 = 27.89 (rounding down)

= 27 modules in series are required to make 1 Series string

If the value are rounded up the voltage will be 1505V (28 * 53.77) which is not acceptable.

Rounding down 27.87 to 27 panels would be better, with this the voltage will be nearly 1500 V i.e., 1451 V.

Determining how many Parallel strings are required:

No. of parallel strings required to meet 1MW power $\frac{Rated\ power}{power\ one\ Series\ string} = \frac{1,000,000}{(670*27)} = 55.29$ (rounding up)

No. of Parallel strings required 56 parallel strings

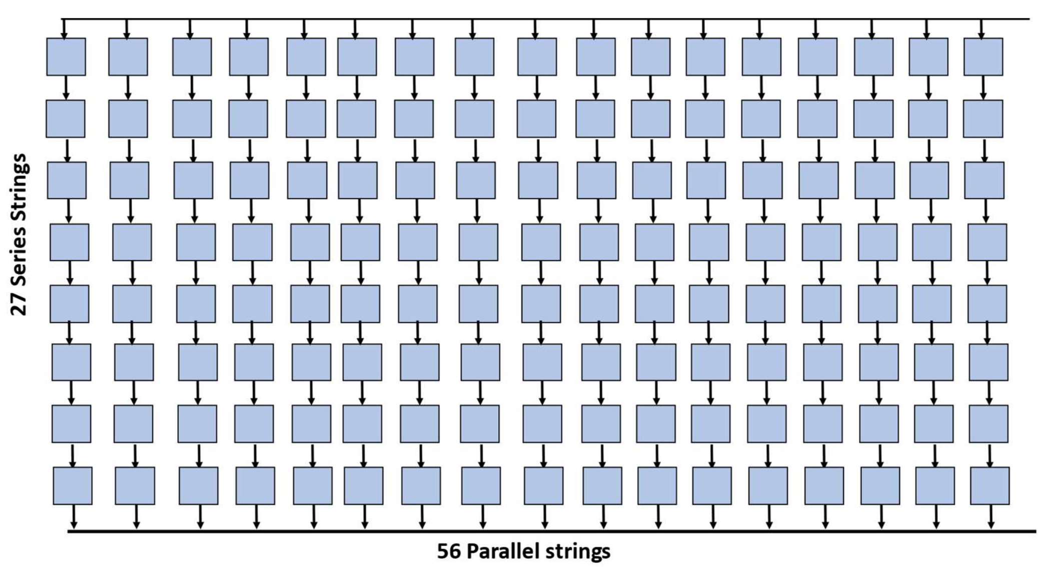


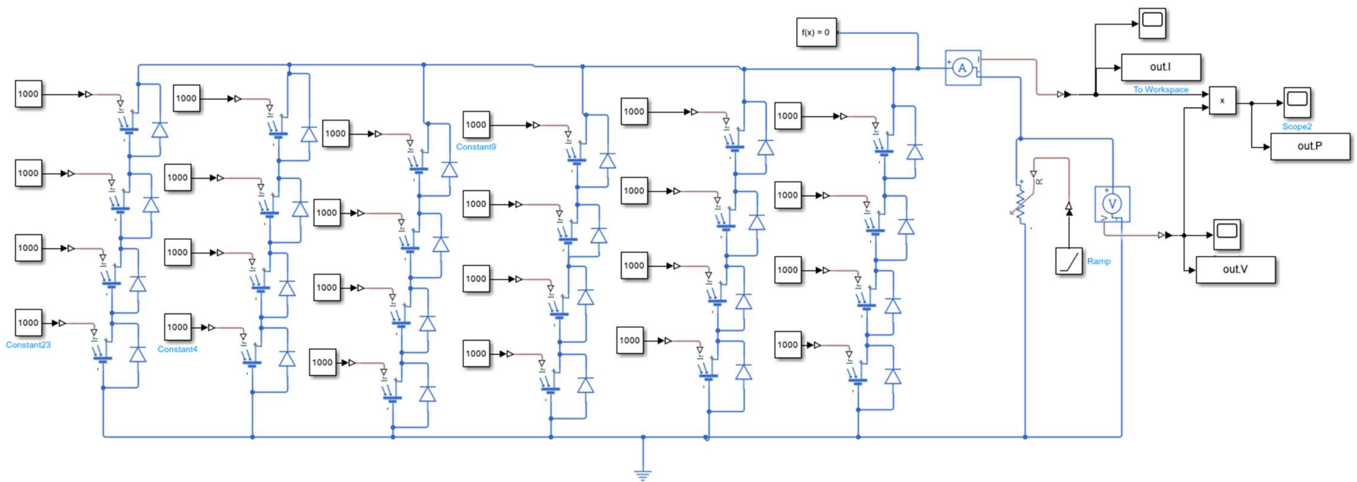
Fig.4 Expected design and placement of PV arrays in series-parallel combination for 1 MW solar plant

Section 3:

In this section we will discuss, how the voltage and current is going to change under:

i) Uniform shading conditions
ii) Non- Uniform shading conditions

I have designed a scaled-down version of PV arrays with 4 series and 6 Parallel strings to meet the rated power and voltage consideration.



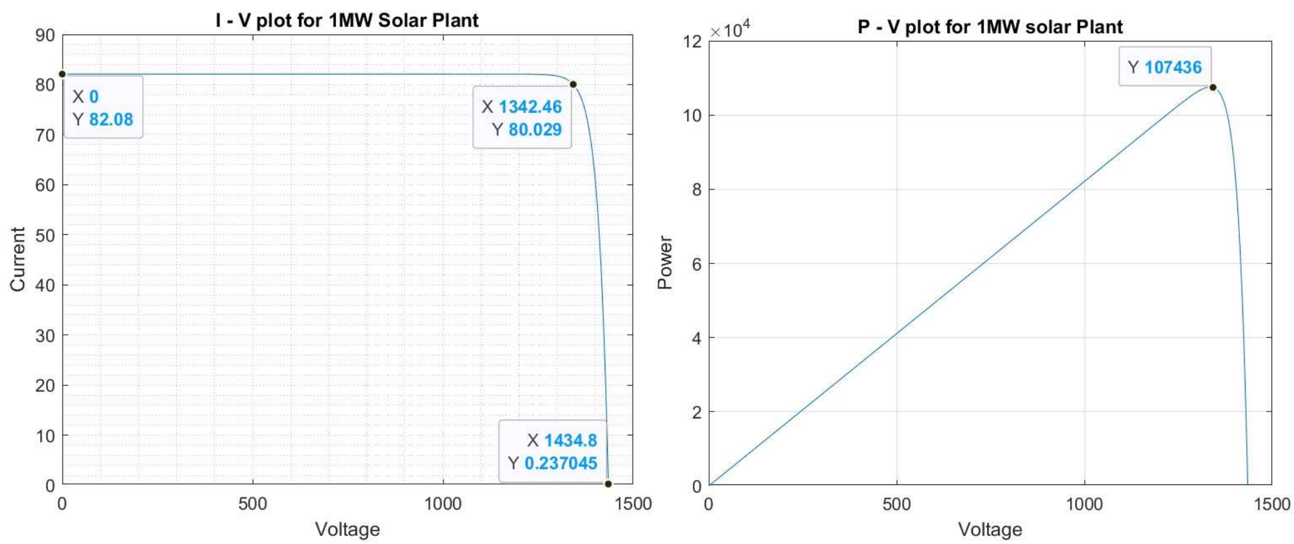
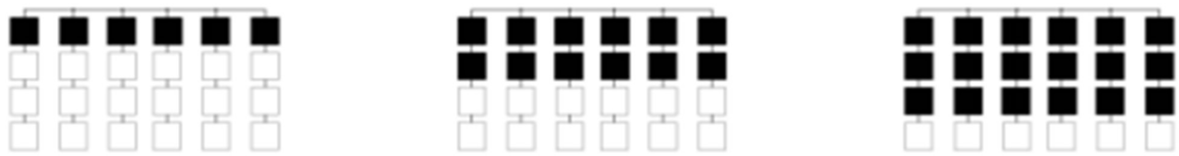


Fig.5 I- V, P- V plots Simulation of Scaled down version at 1000 W/m^2 for 1MW solar plant with 4 series strings & 6 Parallel Strings

Uniform shading:

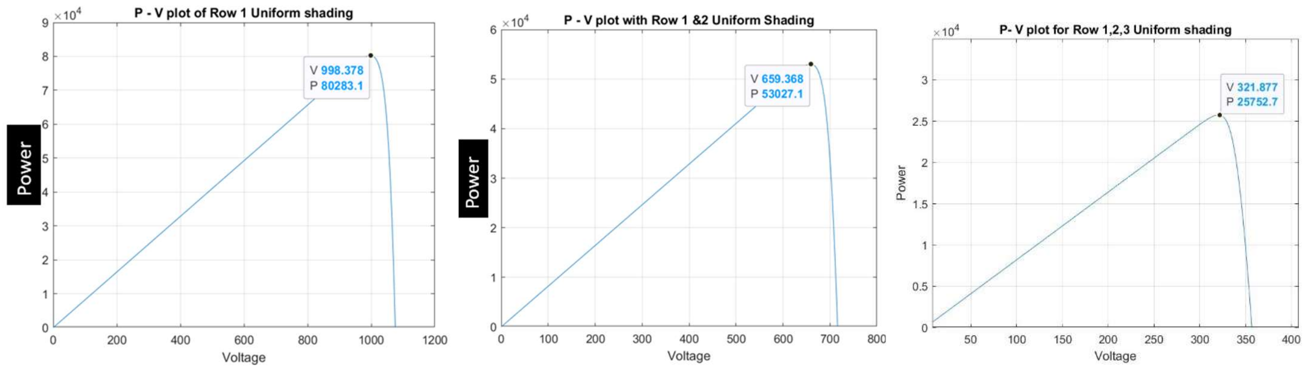
In uniform shading conditions, the I – V and P – V plots will not be disturbed the magnitudes will be changed according to how many rows are shaded. Let’s see in detail with different rows shaded.



(a) 25% of panels are Shaded

(b) 50% of panels are Shaded

(c) 75% of panels are Shaded

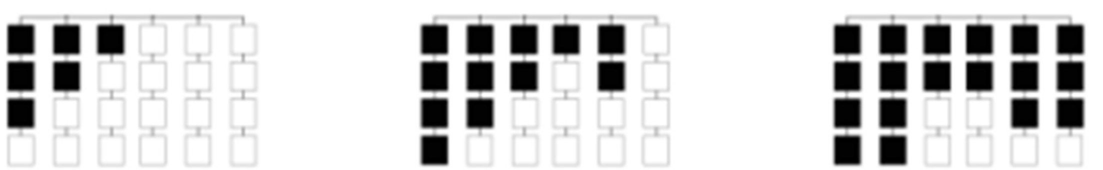


(a) (b) (c)

Fig 6. P – V plots Uniform Shading of the PV arrays with (a) 25 % shaded (b) 50% shaded (c) 75% shaded

Non–Uniform Shading:

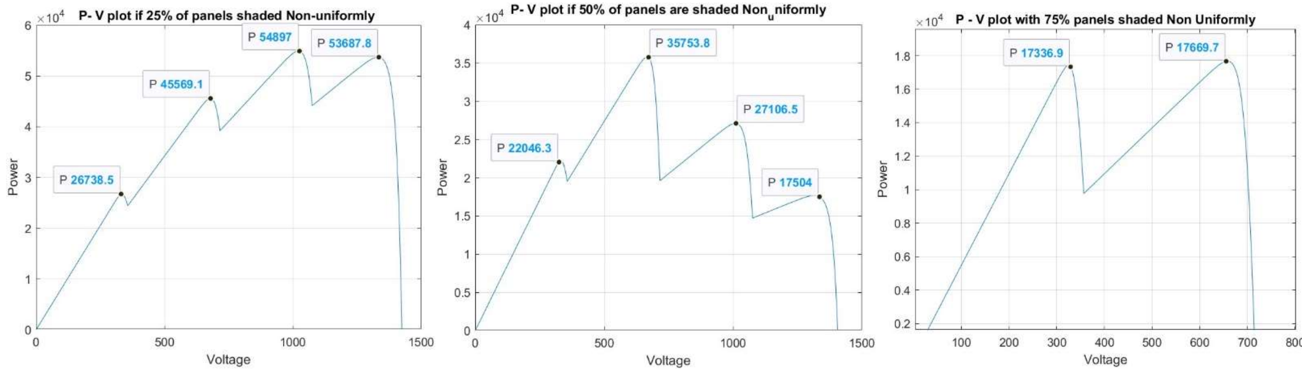
In non-uniform shading conditions, the PV arrays are shaded randomly so that the variations in voltage and power are different let's in detail.



(a) 25% of panels are Shaded

(b) 50% of panels are Shaded

(c) 75% of panels are Shaded



(a) (b) (c)

Fig 7. P – V plots Non- Uniform Shading of the PV arrays with (a) 25 % shaded (b) 50% shaded (c) 75% shaded panels randomly

Section 4:

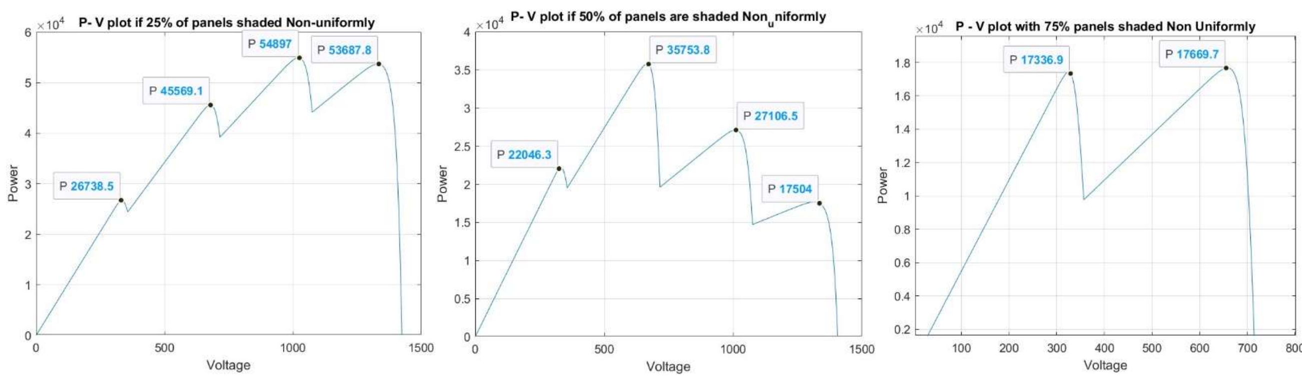
Effect of MPPT in different shading conditions

a) Central MPPT:

i) Uniform Shading:

UNIFORM SHADING CONDITION					
S.NO	**MPP UNSHADED VOLTAGE**	**MPP UNSHADED POWER**	**% OF SHADING**	**MPP VOLTAGE**	**MPP POWER**
1	1342 Volts	1.074 MW	25%	998 Volts	0.802 MW
2			50%	659 Volts	0.530 MW
3			75%	321Volts	0.257 MW

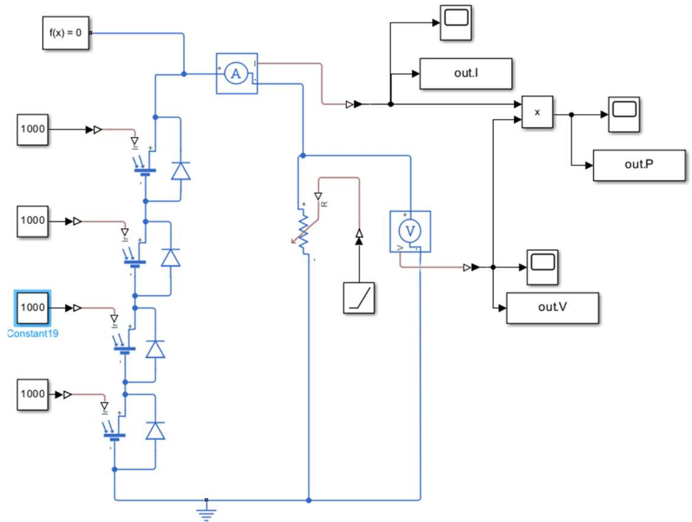
ii) Non-uniform Shading:

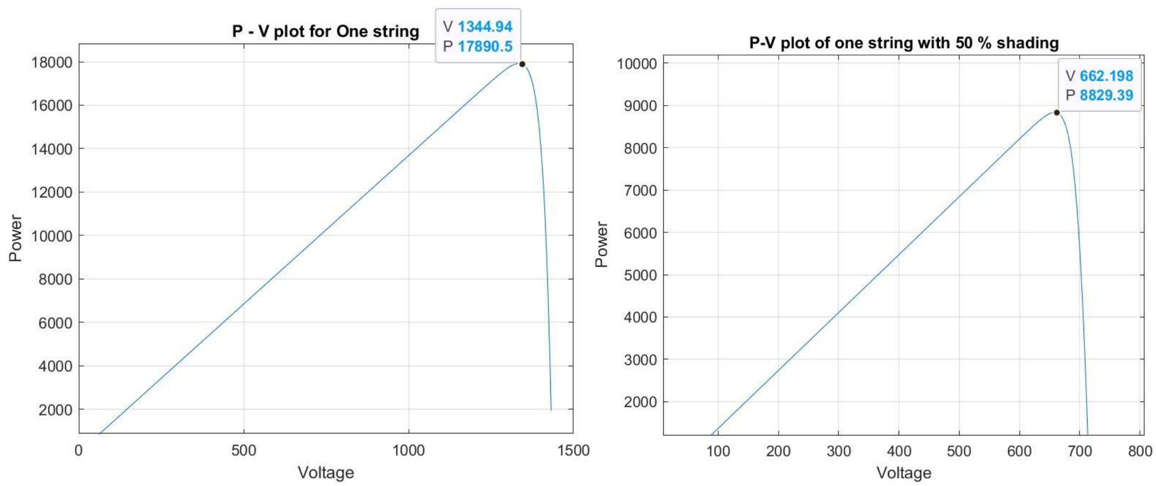


(a) (b) (c)

Fig 8. P – V plots Non- Uniform Shading of the PV arrays with (a) 25 % shaded (b) 50% shaded (c) 75% shaded panels randomly

b) <u>MPPT per String</u>

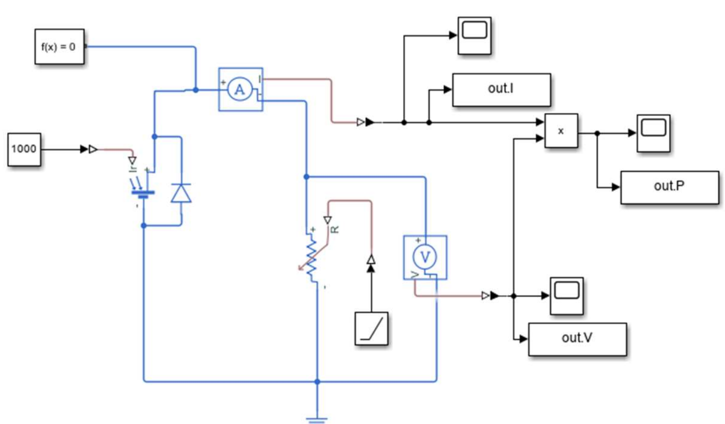


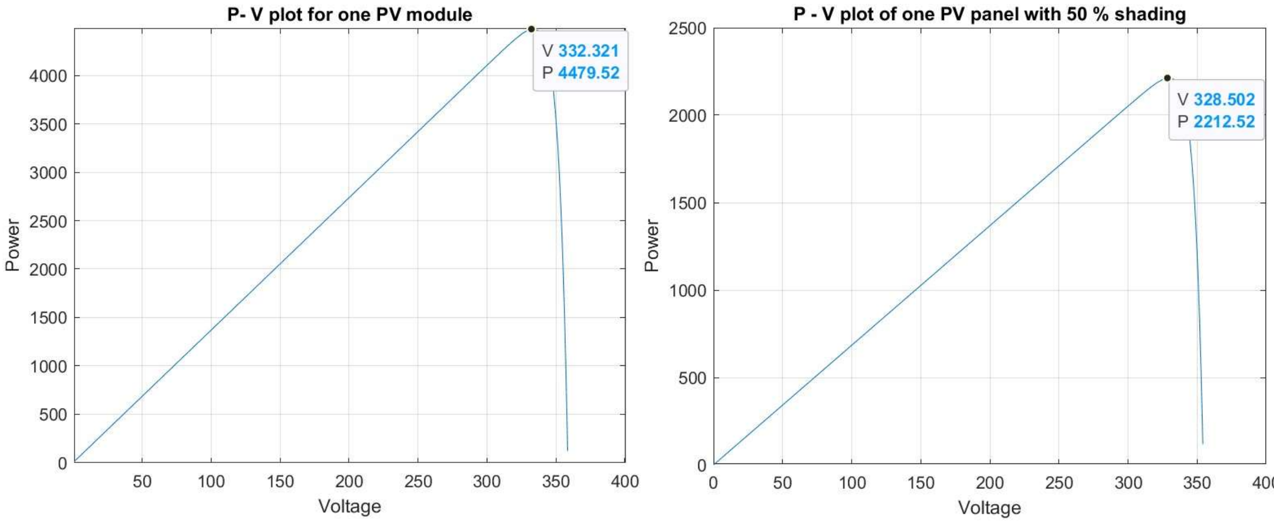


(a) (b)

Fig 9. MPPT for one string with (a) Without Shading (b) 50% shading

c) <u>MPPT per Module:</u>





(a) (b)

Fig 9. MPPT for one module with (a) Without Shading (b) 50% shading