

SOLAR PHOTOVOLTAIC SYSTEM DESIGN FOR RENEWABLE ENERGY HARVESTING

2020 MASTERS THESIS ELECTRICAL & ELECTRONICS ENGINEERING

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SOLAR PHOTOVOLTAIC SYSTEM DESIGN FOR RENEWABLE ENERGY HARVESTING

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T.C

Karabuk University Institute of Graduate Programs Department of Electrical & Electronics Engineering Prepared as Masters Thesis

> KARABUK July 2020

THESIS APPROVAL PAGE

I certify that in my opinion the thesis submitted by Sumair MASHRAF titled "SOLAR PHOTOVOLTAIC SYSTEM DESIGN FOR RENEWABLE ENERGY HARVESTING" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Prof. Dr. İhsan ULUER Thesis Advisor, Department of Electrical & Electronics Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Electrical & Electronics Engineering as a master thesis. July 9, 2020

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The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

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"I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well."

Sumair Mashraf

ABSTRACT

M. Sc. Thesis

SOLAR PHOTOVOLTAIC SYSTEM DESIGN FOR RENEWABLE ENERGY HARVESTING

Sumair Mashraf

Karabük University Institute of Graduate Programs The Department of Electrical and Electronics Engineering

> Thesis Advisor: Prof. Dr. İhsan ULUER July 2020, 69 pages

The maximum power acquired from a solar photovoltaic system differs because of the variety in the barometrical condition. Maximum Power Point Tracking (MPPT) controller is executed to follow the most extreme power as for the adjustments in the climate conditions to proficiently work the solar Photovoltaic (PV) system.

In our thesis, initially we have designed Ground PV Panel system using the Sketchup Pro and AutoCAD software. In the second part of our thesis, we have designed PV system with Perturbation and Observation (P&O) MPPT Algorithm using MATLAB software. The exhibition investigation of independent sunlight based PV system is done under different climate conditions. Buck-Boost converter is embraced as power conditioning unit.

Key Words : Maximum Power Point Tracking (MPPT); Photovoltaic (PV); Perturb and Observe (P&O); AUTOCAD; MATLAB.

Science Code : 701.3.019

ÖZET

Yüksek Lisans Tezi

YENİLENEBİLİR ENERJİ HASARLARI İÇİN GÜNEŞ FOTOVOLTAİK SİSTEM TASARIMI

Sumair Mashraf

Karabük Üniversitesi Lisansüstü Programlar Enstitüsü Elektrik ve Elektronik Mühendisliği Anabilim Dalı

> Tez Danışmanı: Prof. Dr. İhsan ULUER Temmuz 2020, 69 sayfa

Bir güneş fotovoltaik sisteminden elde edilen maksimum güç, barometrik durumdaki çeşitlilik nedeniyle farklılık gösterir. Maksimum Güç Noktası İzleme (MPPT) denetleyicisi, güneş fotovoltaik (PV) sistemini verimli bir şekilde çalıştırmak için iklim koşullarındaki ayarlamalarda olduğu gibi en uç gücü izlemek için yürütülür.

Tezimizde başlangıçta Sketchup Pro ve AutoCAD yazılımını kullanarak Ground PV Panel sistemini tasarladık. Tezimizin ikinci bölümünde MATLAB yazılımını kullanarak Pertürbasyon ve Gözlem (P&O) MPPT Algoritması ile PV sistemi tasarladık. Bağımsız güneş ışığına dayalı PV sisteminin sergi incelemesi farklı iklim koşullarında yapılır. Buck-Boost dönüştürücü güç koşullandırma ünitesi olarak benimsenmiştir.

Anahtar Kelimeler : Maksimum Güç Noktası İzleme (MPPT); Fotovoltaik (PV); Perturb ve Gözlem (P&O); AUTOCAD; MATLAB.

Bilim Kodu : 701.3.019

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CONTENTS

Pa	ge
APPROVAL	d.
ABSTRACT	iv
ÖZET	v
ACKNOWLEDGMENT	vi
CONTENTS	/ii
LIST OF FIGURES	X
LIST OF TABLES	xi
PART 1	. 1
INTRODUCTION	1
1.1.THE IMPORTANCE OF RENEWABLE ENERGY	1
1.2.VARIABLE SOURCES OF RENEWABLE ENERGY	1
1.2.1.Wind Power	1
1.2.2.Small Hydropower	2
1.2.3.Biomass	3
1.2.4.Geothermal	3
1.2.5.Solar power	4
PART 2	5
LITERATURE REVIEW	5
PART 3	7
THEORETICAL BACKGROUND	7
3.1. VARIOUS MPPT TECHNIQUES	7
3.2. PERTURB & OBSERVE	7
3.3. PERTURB & OBSERVE ALGORITHM	8

Page

PART 4	9
DESIGN METHODOLOGY	9
4.1. PV MODULE	9
4.2.PV ARRAY	9
4.3. PV MODELLING	0
4.4. DESIGNING OF THE GROUND PV PANEL SYSTEM	2
4.4.1. Google earth selected area on which pv panel solar system are installed	
information:	2
4.4.2. Ground panel angle calculations1	3
4.4.3.Ground pv panel solar energy system overall power generation14	4
4.5.SKETCHUP MODEL OF GROUND PHOTOVOLTAIC SYSTEM1	5
4.6.AUTOCAD MODEL OF GROUND PHOTOVOLTAIC SYSTEM20	0
4.7. MATLAB SIMULINK MODEL OF PHOTOVOLTAIC CELL2	3
4.7.1.Solar PV Panel block	3
4.7.2.Buck-boost converter block	1
4.7.3. Perturb and observation block	8
4.7.4.Resistance block4	0
4.7.5.Output power block4	2
4.7.6.Demux block4	5
4.7.7.Scope	б
4.7.8.Powergui	б
PART 5	8
SUMMARY	8
5.1. RESULTS & DISCUSSION4	8
5.5.1.Result of sketchup model of ground photovoltaic panel system4	8
5.5.2.Result of Autocad model of ground photovoltaic panel system	1
5.5.3. Simulation result of Matlab model of ground photovoltaic panel system	
with Maximum power point tracking controller54	4
5.2. CONCLUSION	5

REFERENCES
RESUME

LIST OF FIGURES

	Page
Figure 1.1.	Wind power plant
Figure 1.2.	Small Hydro generator - Susasca, Switzerland
Figure 1.3.	Geothermal Energy
Figure 1.4.	Solar Power plant
-	Solar Panel Characteristics Showing MPP And Operating Points A and
Figure 3.2.	Flowchart Of Perturb & Observe Algorithm
Figure 4.1.	Solar Modules
Figure 4.2.	Schematic Cross-Section of a Solar Cell10
Figure 4.3. 1	Equivalent Circuit of PV Cell10
0	41 $^\circ$ 15 $'$ 38 " N , $$ 32 $^\circ$ 41 $'$ 47 " E , Height 530 m, Project application m Karabuk/Safranbolu (Besides Bartin Karabuk yolu Road) Map12
U	Karabuk/Safranbolu (Besides Bartin Karabuk yolu Road) Average per month & Average days with precipitation per month

LIST OF TABLES

Page

Table 1.1. Comparison of global yearly technical potentials of renewable energy	
sources	4
Table 3.1. Comparison of various MPPT Techniques.	7

PART 1

INTRODUCTION

It's positively evident those petroleum derivatives are mutilating the atmosphere and that existing conditions is unsustainable. There is currently an expansive logical agreement that the world needs to lessen ozone harming substance outflows in excess of 25 percent by 2020 - and in excess of 80 percent by 2050.

Sunlight based power, a clean sustainable asset with zero discharge, has enormous capability of energy which can be bridled utilizing an assortment of gadgets. With ongoing advancements, solar systems are effectively accessible for mechanical and household use with the additional favorable position of least upkeep.

1.1 THE IMPORTANCE OF RENEWABLEENERGY

It is the energy which originates naturally, for example, sunlight, wind etc. It is sustainable and could be normally renewed. In this manner, for every single functional reason, these assets can be viewed as limitless, in contrast to waning regular non-renewable energy sources. Aside from the quickly diminishing stores of non-renewable energy sources on the planet, another central point neutralizing nonrenewable energy sources is the contamination related with their burning. Contrastingly, sustainable power destructs impacts of contamination dissimilar to their customary partners.

1.2 VARIABLE MEANS OF RENEWABLE ENERGY 1.2.1 WINDPOWER

Turbines are utilized for bridle the energy accessible of wind streams. Presently, turbines extend from 600 kW to 5 MW evaluated control. Because the power output being of solid shape of breeze speed, it increments quickly through an expansion of

accessible breeze speed. Ongoing headways have prompted aero foil wind turbines, which are progressively proficient because of a superior streamlined structure.



Fig. 1.1 Wind power plant station

1.2.2 SMALL HYDROPOWER

Hydel power generates to a maximum of 10MW. These include changing over the water potential energy put away in dams into usable electrical energy using turbines. Stream hydel electricity intends to use the dynamic water energy without need of structure supplies.



Fig. 1.2 Table Small Hydro generators – Susasca, Switzerland.

1.2.3 BIOMASS

Plants catch solar energy by the procedure of photosynthesis. On combustion, these plants release caught energy. Thusly, biomass functions as characteristic battery to store solar energy and output when necessary.

1.2.4 GEOTHERMAL

It is warm energy which is created and put away into layers of the earth. The gradient accordingly create offers ascend to consistent conduction of warmth from center to earth's outside. This inclination can be used to warm water to deliver superheated steam and use it to run steam turbines to produce power. The fundamental detriment of it is generally constrained to locales close structural limits, however late progressions have prompted the proliferation of this innovation.

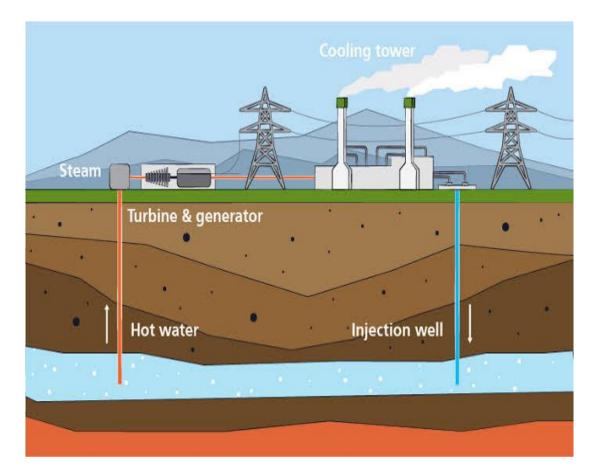


Fig. 1.3 Geothermal Energy

1.2.5 SOLAR POWER

In this thesis, initially we have designed Ground PV Panel system using the AutoCAD and Sketchup Pro software. In the second part of our thesis, we have designed PV system with Perturbation and Observation (P&O) MPPT Algorithm using MATLAB software.

Exhibition investigation of independent sunlight based PV system is done under different climate conditions. Buck-Boost converter is embraced as power conditioning unit.



Fig. 1.4 Solar Power plant

	11-14	Global technical	potential
Renewable energy sources	Unit	Min	Max
	Ele	ectricity production	
Solar energy		60	1 200
Geothermal energy		118	1 1 0 9
Wind energy	EJ/yr	85	580
Ocean energy		7	331
Hydro energy	-	50	52
	Hea	at energy production	
Geothermal energy	EJ/yr	10	312
	Pri	mary energy supply	
Direct solar energy	E I /s ar	1 575	49 837
Biomass energy	EJ/yr	50	500
		1EJ = 278 TWh	

 Table 1.1 Comparison of global yearly technical potentials of renewable energy sources.

PART 2

LITERATURE REVIEW

This thesis introduces an extraordinary well-ordered system for designing Ground PV Panel system using the AutoCAD and Sketch up Pro software and also designing PV system with Perturbation and Observation (P&O) MPPT Algorithm using MATLAB software. [1].

The plan of PV system utilizing straightforward circuit model with definite circuit demonstrating of PV module is exhibited through AutoCAD and Sketch up Pro software. In this thesis, Equivalent circuit of the PV module with Maximum power point tracking (MPPT) controller and Simulink model of every condition has exhibited and complete circuit arranged model has additionally introduced [2].

In this thesis, series of AutoCAD, Sketchup Pro and MATLAB/Simulink. The created model is incorporated with Buck-boost converter with closed loop control of most extreme power point following (MPPT) calculation. Recreation results are approved with the test. [3].

In this thesis, we have designed Safranbolu (Besides Bartin Karabuk Yolu Road) solar energy system using Sketch up Pro software and also solar energy system connection diagram using AutoCAD Software. Our PV module consists of approximately 400 KW installed power in it. The main purpose of the GROUND PV PANEL system is to provide electricity production by utilizing solar energy and to supply this electricity to certain parts of the region in a healthy way.

This proposition displays the structure and utilization of Buck-Boost converter for sun based filled HBLED lighting framework. The proposed framework includes daylight based photovoltaic module, a shut circle buck-help converter. The shut circle buck-help converter is used to change over a low measurement dc input voltage from PV module to a strange state dc voltage required for the pile. To coordinate the yield of the converter, shut circle voltage criticism strategy is used. The criticism voltage is differentiated and a reference voltage and a control signal is made and strengthened. The reenactment considers are finished in MULTISIM. The exploratory results for sun based PV and buck-help converter procured in programming and hardware was presented in this proposition [4].

A Simulation model for generation of single sun oriented cell and two sun based cells in arrangement has been made using Simelectronics (MATLAB/Simulink) condition and was shown in this theory. Sun based cell square is available in simelectronics, with various plots. The effect of assortment of boundaries, for instance, arrangement obstruction Rs, shunt opposition Rsh, diode boundaries: diode submersion current, Is and ideality factor, N are seen a lone sun powered cell. Effect of biological boundaries of temperature assortments could in like manner be seen from duplicated qualities. MATLAB coding has been done to find the most extreme force yield Pm, and voltage at greatest force yield, Vm, of a singular sun based cell and two daylight based cells (in arrangement) under different estimations of boundaries [5]

PART 3

THEORETICAL BACKGROUND

MAXIMUM POWER POINT TRACKING ALGORITHM

3.1 VARIOUS MPPT TECHNIQUES

For tracking the maximum power point the various techniques are:

- 1) Perturb and Observe
- 2) Incremental Conductance method
- 3) Fractional short circuit current
- 4) Fractional open circuit voltage
- 5) Neural networks
- 6) Fuzzy logic

3.2 PERTURB & OBSERVE

MPPT technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, current
Fractional V _{oc}	Medium	Low	Yes	Voltage
Fractional Isc	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

Table 3.1 Comparison of various MPPT Techniques

3.3 PERTURB & OBSERVE ALGORITHM

The Perturb and Observe count communicates when working voltage of photovoltaic board is irritated via little expansion, if the ensuing change in power P is sure that we are leading toward MPP and we keep bothering a comparable way. In case P is negative, we are descending from the course of MPP and the sign of trouble gave should be transformed.

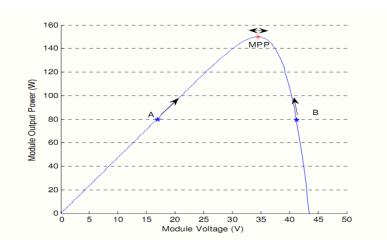


Fig. 3.1 Sun based Panel Characteristics MPP

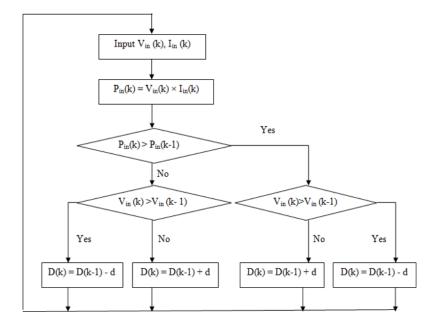


Fig. 3.2 Flowchart Of Perturb & Observe Algorithm

PART 4

DESIGN METHODOLOGY

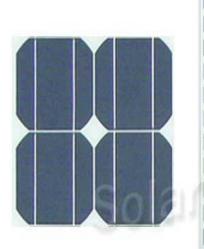
DESIGN OF GROUND PHOTOVOLTAIC SYSTEM AND PHOTOVOLTAIC SYSTEM WITH MAXIMUM POWER POINT TRACKING CONTROLLER

4.1 PVMODULE

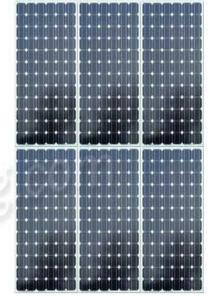
Normally various PV modules are orchestrated in series and parallel to meet the energy prerequisites. They are of various sizes are industrially accessible (for the most part estimated between 60W-170W.

4.2 PVARRAY

It comprises of a few PV cells in series and parallel associations. Series connections are in charge of expanding the voltage of the module though the parallel connections is in charge of expanding the current.







Solar Cells (4 Cells)

Solar Panel (Module) Solar PV Array (Multiple modules)

Fig.4.1 Solar Modules

4.3 PV MODELLING

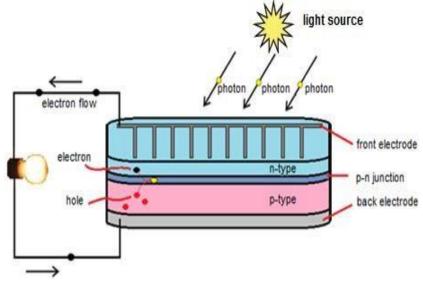


Fig.4.2 Schematic Cross-Section of a Solar Cell

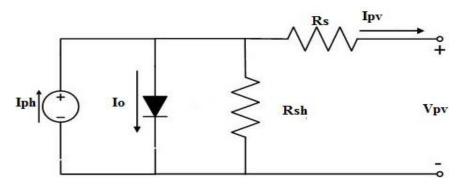


Fig.4.3 PV Cell Equivalent Circuit

The current source I_{pv} - cell photo current, R_{sh} and R_{s} - intrinsic series and shunt resistance of the cell.

Module Photo Current

$$I_{ph} = [I_{scr} + K_i (T - 298)] \times \frac{\lambda}{1000}$$

$$\tag{1}$$

Module Reverse Saturation Current

$$Irs = \frac{I_{scr}}{exp(\frac{qV_{oc}}{NskAt}) - 1}$$
(2)

Module Saturation Current

$$Is = Irs\left[\frac{T}{Tr}\right]^{3} exp\left[\left(q * \frac{Ego}{Bk}\right)\left(\frac{1}{Tr} - \frac{1}{T}\right)\right]$$
(3)

The Current Output of PV module is

$$Ipv = Np \times Iph - Np \times Io\left[exp\left\{q * \frac{Vpv + IpvRs}{NsAkT}\right\} - 1\right]$$
(4)

Where

 $V_{\text{pv}}\text{-}$ output voltage PV module (V)

 I_{pv} - output current PV module (A)

T_r - reference temperature

T - Module operating temperature in Kelvin

 $I_{\text{ph}}\text{-}$ Light generated current in a PV module (A) I_{o}

is the PV module saturation current (A)

A = B is ideality factor = 1.6

K - Boltzmann constant = $1.3805 \times 10-23$ J/K

q - Electron charge = $1.6 \times 10-19$ C

Rs - Series resistance of a PV module

 I_{SCr} - PV module short-circuit current at 25 $^{o}\!C$ and 1000W/m2 = 2.55

 K_i - short-circuit current temperature co-efficient at $I_{SC}r$ = 0.0017A / oC

 λ - PV module illumination (W/m²) = 1000W/m²

 E_{go} - band gap for silicon = 1.1 Ev

Ns - number of cells connected in series

N_p - number of cells connected in parallel

4.4 DESIGNING OF THE GROUND PV PANEL SYSTEM

We have designed Safranbolu (Besides Bartin Karabuk Yolu Road) solar energy system. Our PV module consists of approximately 050 KW installed power in it. This System has an annual approximation of 606, 85MWH that produces large solar energy. The main purpose of the GROUND PV PANEL system is to provide electricity production by utilizing solar energy and to supply this electricity to certain parts of the region in a healthy way.

4.4.1 GOOGLE EARTH SELECTED AREA ON WHICH PV PANEL SOLAR SYSTEM ARE INSTALLED INFORMATION:



Fig. 4.4 41 ° 15 ′ 38 " N , 32 ° 41 ′ 47 " E , Height 530 m, Project application area = 6510 m Karabuk/Safranbolu (Besides Bartin Karabuk yolu Road) Map

4.4.2 GROUND PANEL ANGLE CALCULATION:

We consider our latitude angle equal to direct panel angle (41 °).

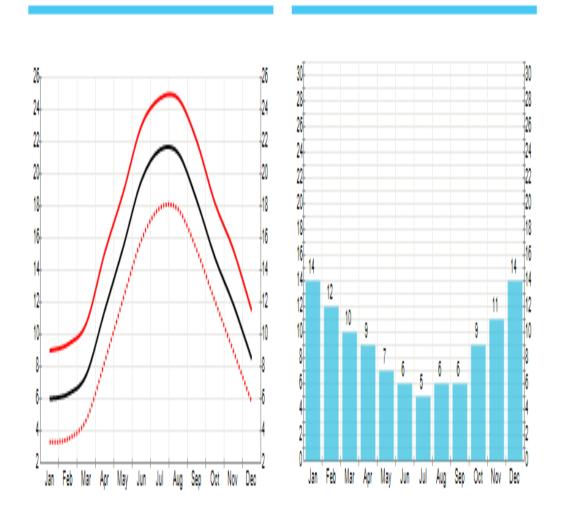
Lattitude angle=Panel angle=41 °

The formula of latitude angle (α) for the entire year,

 $\alpha = (0.75 \times \text{lattitude angle}) + 3$

α=(0.75 ×41)+3≅33

Average temperature per month



Average days with precipitation per month

Fig.4.5 Karabuk/Safranbolu (Besides BartinKarabukyolu Road) Average temperature per month & Average days with precipitation per month

4.4.3 GROUND PV PANEL SOLAR ENERGY SYSTEM OVERALL POWER GENERATION:

Total PV Modules in the project = 1247 PV Modules

Installed Power Account: Pmax=Vmp ×Imp

For single module: P max = $37 \text{ V} \times 8.7 \text{ A} = 321.9 \text{W}$

Installed power for all my site: $1247 \times 321.9W = 401409.3 W$

Shadow Length:

 $L=H/tan\alpha$

α=Ground Panel Angle

H= Height of the obstruction

As our location does not have any obstruction, H will be the overall height of the solar panel. We have chosen Canadian solar polycrystalline pv panel for our design whose dimensions are 1.651 m x 1 m x 0.039 m respectively.

Now, in software design we have adjoined 3 solar panels together forming an array.

We know breadth of each solar panel

Thus total breadth b=1m,

Joining 3 solar panels, Total breadth B=3m,

Now to calculate H,

We have Sin (33) = H/3, H=3 x Sin(33) = 1.639m,

From above Ground Panel angel calculations we have,

 α =33 and θ = 41 °.

Now, Substituting α =33 and H= 0.544 in below formula

 $L=H/tan\alpha$

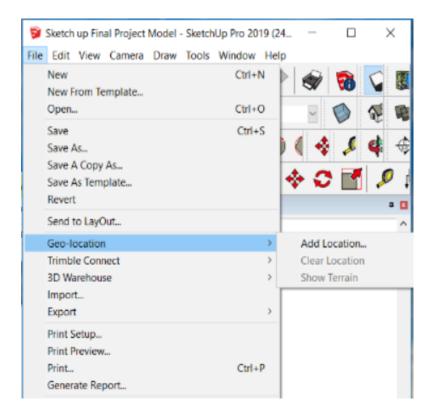
L=1.639/ (tan (33))

L=2.52m

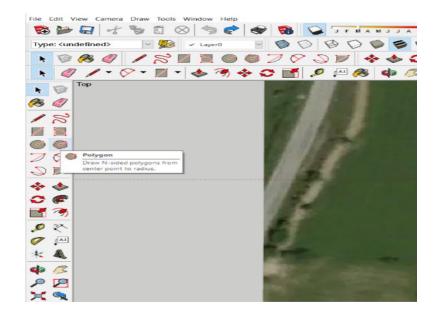
Thus, the distance between two solar panels in our design is 2.52m.

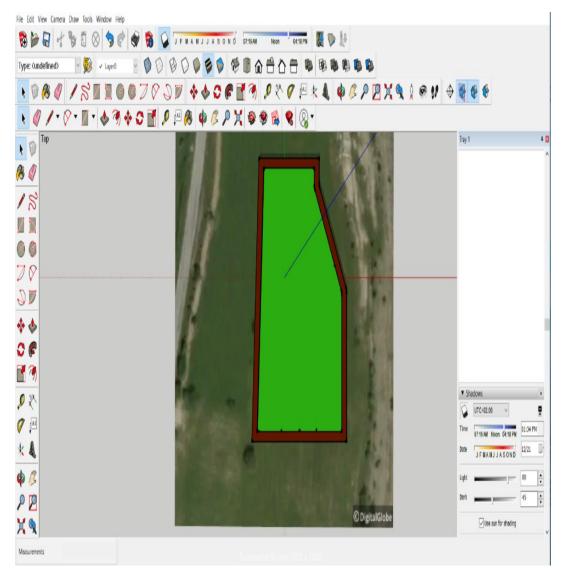
4.5 SKETCHUP MODEL OF GROUND PHOTOVOLTAIC SYSTEM

Step 1: Open Sketch up pro software and Click on file > Geo-location.. Click on Geo-location> Add location. Then, the software opens up Google earth, thus from it we choose the region we would like to establish ground PV panel system. In our case, we have chosen Safranbolu (Besides Bartin Karabuk Yolu Road).



Step 2: After choosing the area we draw required shape faces from corner to corner on our location and also we design boundaries to our PV Panel system using drawing tools> Polygon in the software and choose our required shape. In our case, we have chosen the following polygon face and highlighted our polygon face's ground that is to be covered the solar panel in GREEN Color and the boundaries to our system in BROWN color using respectively.

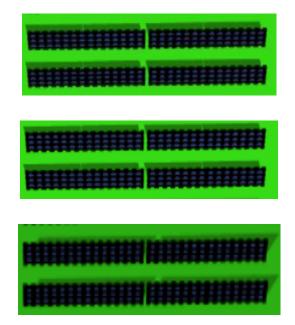


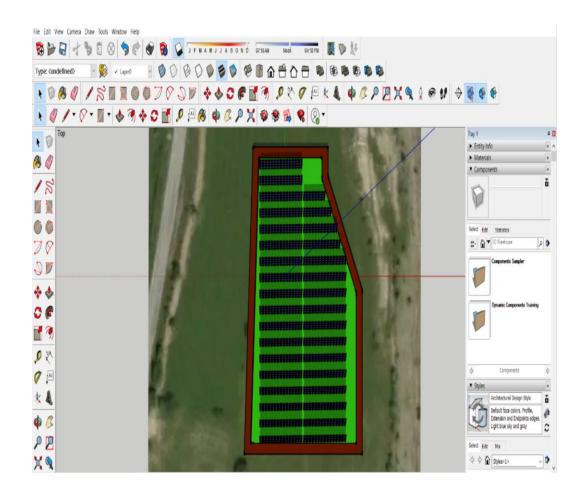


Step 3: Nextly, to add solar panels with slope. We select tray block in sketchup pro Tray> then we choose Components, Components> we search for Solar arrays.

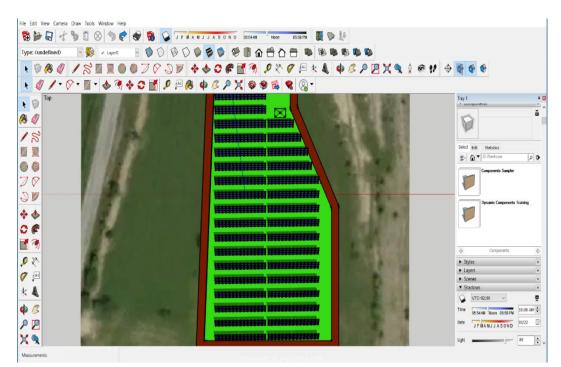
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Step 4: In tray block, we have Shadows block. Thus by analyzing the shadow length of one solar panel array as shown. We make a ground PV panel system by an arrangement of 1247 modules in similar manner.



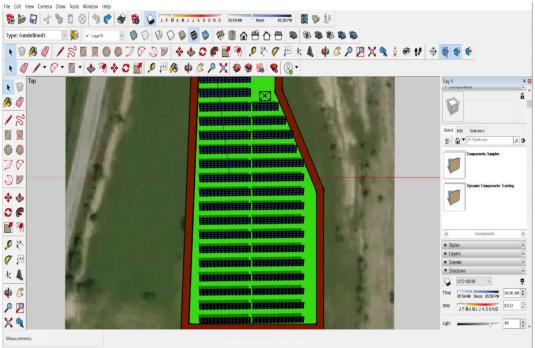


Step 5: After making the desired solar panel arrangement, we then using the drawing tool create a AC Box in order to show in the model that the solar PV Panels convert the given solar energy and supply the electrical energy to inverters and finally to the AC box placed as shown and place it accordingly.

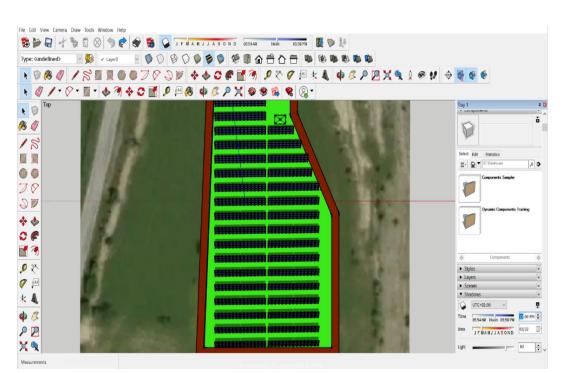


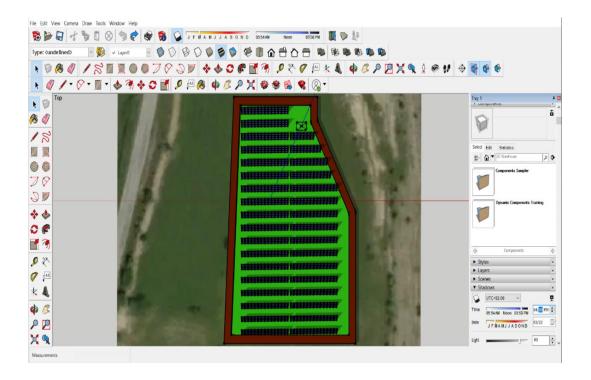
Step 6: Thus, we have finally made a sketch up of our Ground solar PV Panel system.

Step 7: Using the shadow tool in Tray block of Sketch up pro, we then can analyze the solar energy that falls on our Ground PV panel system at any month and at any time of the day. For example, let us analyze solar energy that falls on our solar panel on March 22, 2019 at 10 AM, 12 PM, 4 PM.



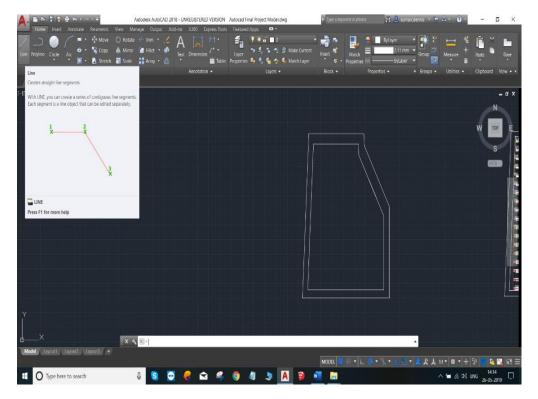






4.6 AUTOCAD MODEL OF GROUND PHOTOVOLTAIC SYSTEM

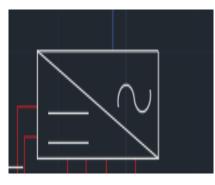
Step 1: After we obtain the resultant model of our ground PV panel system, we make the AutoCAD modeling of our system to study and understand the electrical connections for the components of our system. Open AutoCAD, select Line block and create the outline face of our PV Panel system.

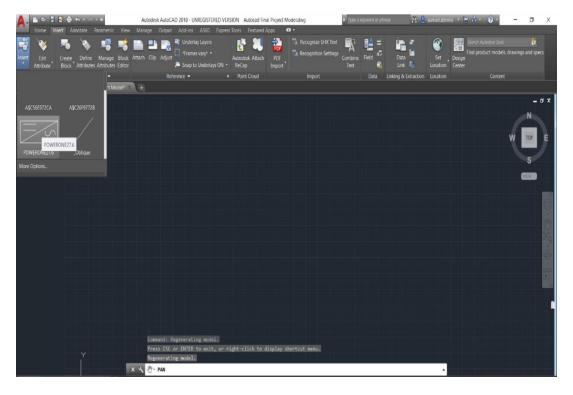


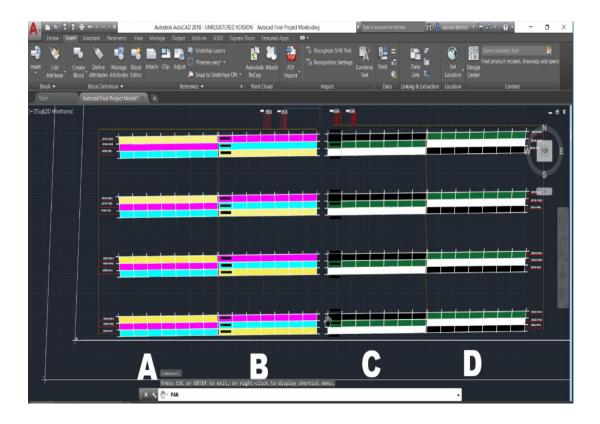
Step 2: Using the same line block create a single solar array, add colors to them as shown. As we have larger number of solar modules, we divide our solar panels arrays as A, B, C and D.



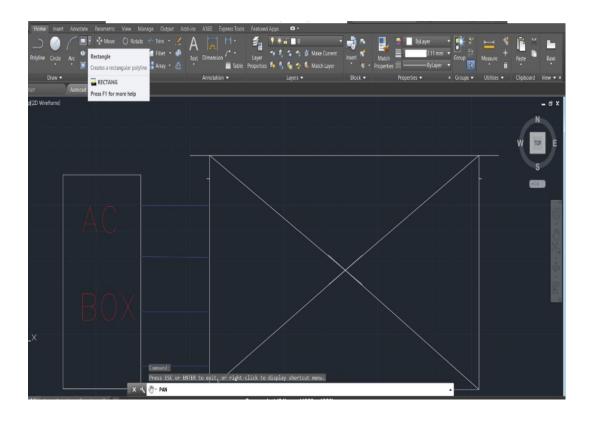
Step 3: Now we create a module array and add the inverters to our solar arrays and make the connections between the Inverter and the solar arrays as shown. By selecting Insert > POWERONE27.6. Totally we create 17 inverters.





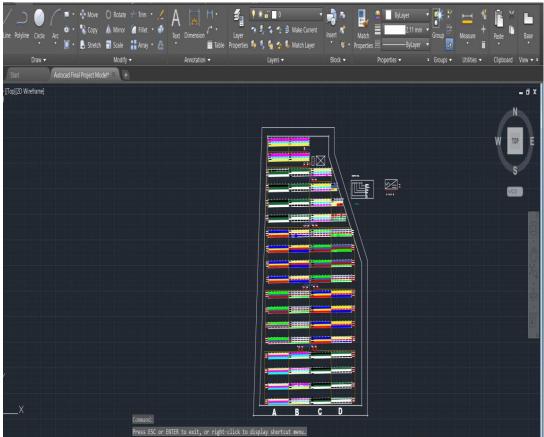


Step 4: After the inverters are connected to the solar panel we create a AC Box by selecting Rectangle and renaming it and finally make connections between the Inverters to the AC Box.



Step 5: Thus the resultant Interconnection model of our Ground PV panel system

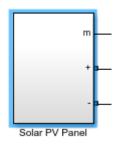
in AutoCAD is modeled.



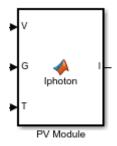
4.7 MATLAB SIMULINK MODEL OF PHOTOVOLTAICCELL

4.7.1 SOLAR PV PANEL BLOCK

Step 1: We add a Solar PV Panel subsystem block from Simulink Library > Subsystem.



Step 2: Inside Solar PV Panel subsystem block, We add a MATLAB Function file from Simulink Library >Matlab function (PV Module).



Step 3: Write the following program in the PV Module MATLAB function file.

% Solar Panel Simulation Model

function I = Iphoton(V, G, T)

- % I output current (ampere)
- % V output voltage (volt)
- % G operating solar irradiation (kW m-2)
- % T operating temperature (C)
- % k bolzmann's constant (J/K or m2 kg s-2 K-1)
- % q electron charge (coulomb)
- % n ideal factor dependent of the PV characteristics
- % ki short-circuit current temperature coefficient (A/K)
- % Eg band gap energy of semiconductor used in a cell (eV)
- % Ns number of cell in series
- % Np number of cell in parallel
- % Tr reference temperature at STC (K)
- % Voc open circuit voltage (volt)

- % Iph photo current (ampere)
- % Isc short circuit current (ampere)
- % Is cell saturation current (ampere)
- % Ir cell reverse saturation current (ampere)
- % Rs Series Resistance (ohm)
- % Rsh Shunt Resistance (ohm), here it is inf
- k = 1.3806488e-23;
- q = 1.6021766e-19;
- n = 1.3; % 1.3 for poly crystalline solar cell (1<n<2)
- ki = 1.33e-3; % 0.065A/C
- Eg = 1.12; % Si-1.12, GaAs-1.42
- Ns = 10;
- Np=6;
- Tr = 273.15+25; % 25C 0C=273.15K
- Voc = 37.51/Ns;
- Isc = 8.63/Np;
- Tk = 273.15 + T;
- Vc = V/Ns;
- $Vt = (n^{*}k^{*}Tr) / q;$
- Vta = (n*k*Tk) / q;
- $b = (Eg^*q) / (n^*k);$

% photo current at operating temperature

Iss = Isc * (1 + (ki * (Tk - Tr)));

% photo current at operating irradiation

Iph = G * Iss;

% Io

Ir = Isc / (exp(Voc / Vt) - 1);

Is = Ir * $(Tk/Tr)^{(3/n)} * \exp(b * (1/Tr - 1/Tk));$

% calculation for Rs using slope of I-V curve

dVdI = -2.0/Ns; % Take dV/dI at Voc from I-V curve of datasheet

Xv = Ir / Vt * exp(Voc / Vt);

 $\mathbf{Rs} = - \, \mathbf{dV} \mathbf{dI} - 1/\mathbf{Xv};$

% I = Iph - Is * $(\exp((Vc + I * Rs) / Vta) - 1)$

% f(I) = Iph - I - Is * (exp((Vc + I * Rs) / Vta) - 1) = 0

% Solve for I by Newton's method: Ia2 = Ia1 - f(Ia1)/f'(Ia1)

% Initialize I with zeros

I = zeros(size(Vc));

for j=1:5;

I = I - (Iph - I - Is .* (exp((Vc + I .* Rs) ./ Vta) -1))...

end

I=I*Np;

End

Step 4: We add a Step radiation to our PV module from Simulink Library file > Step and give the following parameters to our radiation block.

Block Parameters: radiation	
Step	
Output a step.	
Parameters	
Step time:	
0	
Initial value:	
0	
Final value:	
1	
Sample time:	
0	
✓ Interpret vector parameters as 1-D	
✓ Enable zero-crossing detection	
OK Cancel	Help Apply

Step 5: We add a constant temperature block from Simulink Library file > Constant and give the following parameters to our temperature block.

	🔁 Block Parameters: Temperature	×
	Constant	
	Output the constant specified by the 'Constant value' parameter. If 'Constant value' is a vector and 'Interpret vector parameters as 1-D' is on, treat the constant value as a 1-D array. Otherwise, output a matrix with the same dimensions as the constant value.	
	Main Signal Attributes	
	Constant value:	
	60	:
	☑ Interpret vector parameters as 1-D	
	Sample time:	
	inf	:
60		
nperature	OK Cancel Help Appl	у

Temp

Step 6: We add a Controlled Current Source from Simulink library file > Controlled Current Source give the following parameters to our Controlled Current Source block.

	Block Parameters: Current Source X
	Controlled Current Source (mask) (link)
	Converts the Simulink input signal into an equivalent current source. The generated current is driven by the input signal of the block.
	You can initialize your circuit with a specific AC or DC current. If you want to start the simulation in steady-state, the block input must be connected to a signal starting as a sinusoidal or DC waveform corresponding to the initial values.
	Parameters
	✓ Initialize
	Source type DC -
	Initial amplitude (A):
1	0
_	Measurements None -
ý g	
↑ ⊺	OK Cancel Help Apply

Step 7: We add a Diode block from Simulink Library file > Diode and give the following parameters to our diode block.

	🛅 Block Parameters: Diode	\times
	Diode (mask) (link)	^
	Implements a diode in parallel with a series RC snubber circuit. In on-state the Diode model has an internal resistance (Ron) and inductance (Lon). For most applications the internal inductance should be set to zero. The Diode impedance is infinite in off-state mode.	
	Parameters	
	Resistance Ron (Ohms) :	
	0.001	
	Inductance Lon (H) :	
	0	
	Forward voltage Vf (V) :	
	0	
	Initial current Ic (A) :	
	0	
	Snubber resistance Rs (Ohms) :	
	500	
	Snubber capacitance Cs (F) :	
	250e-9	
E - M	Show measurement port	
卒創		~
_ _	OK Cancel Help Apply	1

Step 8: We add a Voltage measurement block from Simulink Library file > voltage measurement gives the following parameters to our voltage measurement block.

	🔁 Block Parameters: Voltage Measurement	Х
	Voltage Measurement (mask) (link)	
	Ideal voltage measurement. The Output signal parameter is disabled when the block is not used in a phasor simulation. The phasor simulation is activated by a Powergui block placed in the model.	
	Parameters	
	Output signal : Complex	•
+ v	OK Cancel Help Appl	у

Step 9: We add a PMC Port from Simulink Library file >PMC_port and give the following parameters to our PMC port block.

	Block Parameters: +	×
	PMC_Port	
	Physical Modeling Connection Port block for subsystems	
	Parameters	
	Port number:	
	1	
Ā	Port location on parent subsystem: Right	•
	OK Cancel Help Appl	у

Step 10: Following Step 8, we add a similar PMC Port 2 and connect as shown.

-4

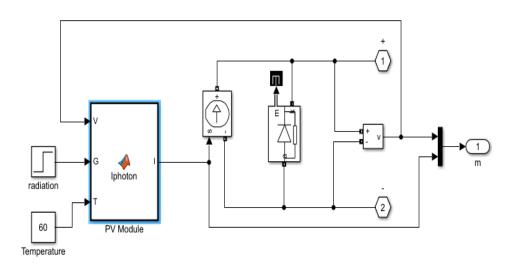
Step 11: We add a Mux block from Simulink Library file > Mux as shown and give the following parameters to our mux block.

	🚹 Block Parameters: Mu	IX			\times
	Mux				
	Multiplex scalar or ver	ctor signals.			
	Parameters				
	Number of inputs:				
	2				
	Display option: bar				•
-	L				
•	-				
		OK	Cancel	Help	Apply

Step12: We add an Outport block from Simulink Library file >Outport and we give the following parameters to our Outport block.

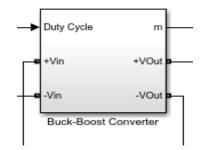
	Block Parameters: m	\times
	Outport	_
	Provide an output port for a subsystem or model. The 'Output when disabled' and 'Initial output' parameters only apply to conditionally executed subsystems. When a conditionally executed subsystem is disabled, the output is either held at its last value or set to the 'Initial output'.	
	Main Signal Attributes	
	Port number:	
	1	
	Icon display: Port number	-
		_
		- 1
		- 1
		- 1
		- 1
		- 1
		,
		- 1
		- 1
▶(1)		- 1
m		
	OK Cancel Help Apply	r

Step 13: Connect all the blocks from step 1 to step 12 as shown.



4.7.2 BUCK-BOOST CONVERTER BLOCK:

Step1: We add a Buck boost converter block from Simulink Library file > Subsystem



- Step 2: Inside Buck-boost converter subsystem block, we add a required circuit model of buck boost converter.
- Step 3: We add 1 Input port , (1,2 Input PMC ports and 3,4- Output PMC ports) to our Simulink library.



Step 4: We add a subsystem for pulse generator block.



Step 5: Inside the pulse generator block we build the following equivalent circuit.

Step 6: Inside the pulse generator block:

1. We add the inport port 1

2. We add Repeating table block from Simulink Library file > Repeating table and give the following parameters to Repeating table block.

	🎦 Block Parameters: Rep	eating Sequer	nce1		×
	- Repeating table (mask	(link)			
	Output a repeating set value pairs. Values of				
	Parameters				
	Time values:				
	[0 1/10e3]				:
	Output values:				
	[0 1]				:
MI-					
		OK	Cancel	Help	Apply

3. We add a summation block from Simulink Library file > sum and give the following parameters to summation block.

	Block Parameters: Subtract Sum Add or subtract inputs. Specify one of the following: a) character vector containing + or - for each input port, for spacer between ports (e.g. ++ - ++) b) scalar, >= 1, specifies the number of input ports to be summed. When there is only one input port, add or subtract elements over all dimensions or one specified dimension	×
	Main Signal Attributes Icon shape: rectangular List of signs: +-	•
→ -		

4. We add a relay block from Simulink Library file > relay and give the following parameters to relay block.

	Block Parameters: Relay1	\times
	Relay	
	Output the specified 'on' or 'off' value by comparing the input to the specified thresholds. The on/off state of the relay is not affected by input between the upper and lower limits.	
	Main Signal Attributes	
	Switch on point:	
	eps	Ξ
	Switch off point:	
	eps	Ξ
	Output when on:	
	1	Ξ
	Output when off:	
	0	:
	Input processing: Elements as channels (sample based)	•
▶	Enable zero-crossing detection	
_	OK Cancel Help Appl	y

5. We add a data type conversion block from Simulink Library file > data type conversion and give the following parameters to data type conversion block.

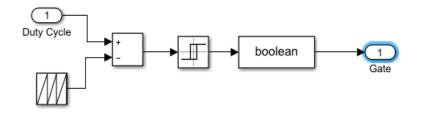
	눰 Block Parameters: Data Type Conversion	\times
	Data Type Conversion	
	Convert the input to the data type and scaling of the output.	
	The conversion has two possible goals. One goal is to have the Real World Values of the input and the output be equal. The other goal is have the Stored Integer Values of the input and the output be equal. Overflows and quantization errors can prevent the goal from being fu achieved.	
	Parameters	
	Output minimum: Output maximum:	
		:
	Output data type: boolean >>	
	Lock output data type setting against changes by the fixed-point t	ools
	Input and output to have equal: Real World Value (RWV)	-
	Integer rounding mode: Zero	•
boolean	Saturate on integer overflow	
	OK Cancel Help Ap	oly

6. We add the outport 1

ł



7. Connect all the above blocks as shown.



Step 7: We add Inductor L1 from Simulink Library file > Series RLC branch and give the following parameters to it.

	Block Parameters: L1 ×
	Series RLC Branch (mask) (link)
	Implements a series branch of RLC elements. Use the 'Branch type' parameter to add or remove elements from the branch.
	Parameters
	Branch type: L
	Inductance (H):
	1000e-6
	Set the initial inductor current
	Measurements Branch voltage and current
LI	OK Cancel Help Apply

Step 8: We add Capactor C1 from Simulink Library file > Series RLC branch and give the following parameters to it.

	Block Parameters: C1 X
	Series RLC Branch (mask) (link)
	Implements a series branch of RLC elements. Use the 'Branch type' parameter to add or remove elements from the branch.
	Parameters
	Branch type: C
	Capacitance (F):
	2000e-6
	Set the initial capacitor voltage
+	Measurements Branch voltage and current
c1 —	
	OK Cancel Help Apply

Step 9: We add IGBT, connect it to the terminator from Simulink Library file > IGBT, and give the following parameters to it.

	🔁 Block Parameters: IGBT	\times
	IGBT (mask) (link)	^
	Implements an IGBT device in parallel with a series RC snubber circuit. In on-state the IGBT model has internal resistance (Ron) and inductance (Lon). For most applications, Lon should be set to zero. In off-state the IGBT model has infinite impedance.	
	Parameters	
	Resistance Ron (Ohms) :	
	0.001	
	Inductance Lon (H) :	
	0	
	Forward voltage Vf (V) :	
	2.5	
	Initial current Ic (A) :	
	0	
	Snubber resistance Rs (Ohms) :	
	1e5	
	Snubber capacitance Cs (F) :	
	inf	
╼ <mark>┑<u>╷</u>╓╼╼<u></u> ╼┎╱╶╦_{┍╒}╻</mark>	Show measurement port	~
IGBT	OK Cancel Help App	ly

Step 10: We add Inductor L2 from Simulink Library file > Series RLC branch and give the following parameters to it.

		Block Parameters: L ×
		Series RLC Branch (mask) (link)
		Implements a series branch of RLC elements. Use the 'Branch type' parameter to add or remove elements from the branch.
		Parameters
		Branch type: L
		Inductance (H):
	3	47e-6 :
¢		Set the initial inductor current
Ľ	>	Measurements Branch voltage and current
1		OK Cancel Help Apply

Step 11: We add DIODE, connect it to the terminator from Simulink Library file > Diode, and give the following parameters to it.

	Block Parameters: Diode	\times
	Diode (mask) (link)	^
	Implements a diode in parallel with a series RC snubber circuit. In on-state the Diode model has an internal resistance (Ron) and inductance (Lon). For most applications the internal inductance should be set to zero. The Diode impedance is infinite in off-state mode.	
	Parameters	
	Resistance Ron (Ohms) :	
	0.001	
	Inductance Lon (H) :	
	0	
	Forward voltage Vf (V) :	
	0.8	
	Initial current Ic (A) :	
	0	
	Snubber resistance Rs (Ohms) :	
	1000	
	Snubber capacitance Cs (F) :	
Diode	500e-9	
E←m	Show measurement port	
		~
	OK Cancel Help Appl	у

Step 12: We add Capacitor C2 from Simulink Library file > Series RLC branch and give

the following parameters to it.

	Block Parameters: C2 ×
	Series RLC Branch (mask) (link)
	Implements a series branch of RLC elements. Use the 'Branch type' parameter to add or remove elements from the branch.
	Parameters
Ţ	Branch type: C
Ŧ	Capacitance (F):
	2000e-6 :
C2	Set the initial capacitor voltage
\uparrow	Measurements Branch voltage and current
P	OK Cancel Help Apply

Step 13: We add voltage measurement block from Simulink Library file > Voltage measurement and give the following parameters to it.

Block Parameters: Voltage1

	Voltage Measurement (mask) (link)
	Ideal voltage measurement. The Output signal parameter is disabled when the block is not used in a phasor simulation. The phasor simulation is activated by a Powergui block placed in the model.
	Parameters
	Output signal : Complex -
┛╴╵	
	OK Cancel Help Apply

 \times

Step 14: We add current measurement block from Simulink Library file > current

measurement and give the following parameters to it.

	Block Parameters: Current Measurement	\times
	Current Measurement (mask) (link)	
	Ideal current measurement. The Output signal parameter is disabled when the block is not used in a phasor simulation. The phasor simulation is activated by a Powergui block placed in the model.	
	Parameters	
	Output signal : Complex	-
-• • + - b	-	
	OK Cancel Help App	ly

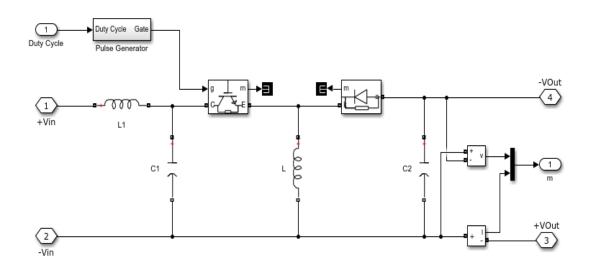
Step 15: We add Mux from Simulink Library file > mux and give the following

	parameters to it.	
	Block Parameters: Mux	\times
	Mux	
	Multiplex scalar or vector signals. Parameters	
	Number of inputs:	
	2	
1	Display option: bar	-
→		
-	OK Cancel Help Apply	/

Step 16: We add Outport 1.



Step 17: Connect all the blocks from step 3 until step 16 as shown below to obtain the equivalent model.



4.7.3 PERTURB AND OBSERVATION MPPT CONTROLLER BLOCK :

Step 1: We create a Perturb and Observation MPPT Controller subsystem block from Simulink Library > Subsystem.



- Step 2: Inside the MPPT Controller subsystem block, we add a required circuit model of MPPT Controller.
- Step 3: Inside the MPPT Controller subsystem block,
 - 1. We add the Inport 1

1 Signal

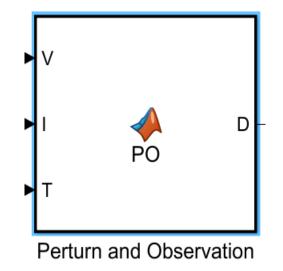
2. We add digital clock block from Simulink Library file > digital clock and give the following parameters to it

	Block Parameters: Digital Clock	\times
	Digital Clock Output current simulation time at the specified rate.	
12:34	Parameters Sample time: 0.001	E
Digital Clock	OK Cancel Help	Apply

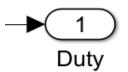
 We add a Demux block from Simulink Library file >demux and give the following parameters to it.

	Block Parameters: Demux X
	Demux
	Split vector signals into scalars or smaller vectors. Check 'Bus Selection Mode' to split bus signals.
	Parameters
	Number of outputs:
	2
	Display option: bar
	Bus selection mode
┢	
	OK Cancel Help Apply

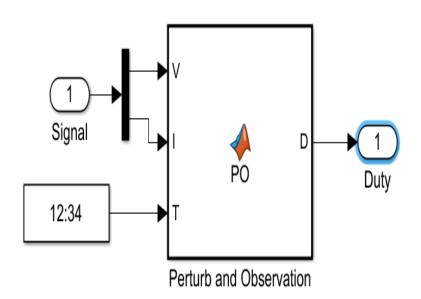
4. We add a MATLAB Function file from Simulink Library >Matlab function (Perturb and Observation)



5. We add out port 1.

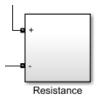


6. Connect all the above blocks as shown.



4.7.4 RESISTANCE BLOCK:

Step 1: We create a Resistance subsystem block from Simulink Library > Subsystem.



Step 2: Inside the Resistance subsystem block we build the following residual circuit.

Step 3: Inside the Resistance subsystem block

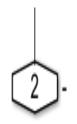
1. We add PMC Port 1 from the Simulink library > PMC port and give the following parameters to it.



 We add resistance R from the Simulink library > Series RLC branch and give the following parameters to it.



3. We add PMC Port 2 from the Simulink library > PMC port and give the following parameters to it.



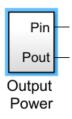
We create X, Y goto tags from the Simulink library >goto tag and give t

following parameters to it.

	🚹 Block Parameters: Go	to			×
	Goto				
	Send signals to From 'scoped', then a Goto visibility of the tag. T tags are enclosed in t braces, {}).	Tag Visibility blo he block icon di	ock must be u splays the sel	sed to define ected tag nam	the ne (local
	Arguments				
	Goto tag: X	Re	ename All	Tag visibility:	global 🝷
	Corresponding bl Photovoltaic_Co Power/From2		ect_Matlab_M	odel/Output	refresh
	Icon display: Tag				•
Ś					
		OK	Cancel	Help	Apply
	Block Parameters: Got	to1			×
	Goto				
	Send signals to From I 'scoped', then a Goto visibility of the tag. Ti tags are enclosed in b braces, {}).	Tag Visibility blo he block icon di	ock must be u splays the sel	sed to define ected tag nan	the ne (local
	Arguments				
	Goto tag: Y	Re	ename All	Fag visibility:	global 🝷
	Corresponding blocks: refresh Photovoltaic_Course_Final_Project_Matlab_Model/Output Power/From1				
→ (Y]	Icon display: Tag				•
		ОК	Cancel	Help	Apply

4.7.5 OUTPUT POWER BLOCK:

Step 1: We create output power subsystem block from Simulink Library > Subsystem.



Step 2: Inside the output power subsystem block we build the following residual circuit.

Step 3: Inside the output power subsystem block,

1. We add X,Y from tag from Simulink library > from and give the following parameters to it.

	Block Parameters: From 2						
	From						
	Receive signals from the Goto block with the specified tag. If the tag is defined as 'scoped' in the Goto block, then a Goto Tag Visibility block must be used to define the visibility of the tag. After 'Update Diagram', the block icon displays the selected tag name (local tags are enclosed in brackets, [], and scoped tag names are enclosed in braces, {}).						
	Arguments						
	Goto tag: X V Update Tags						
	Goto source: Photovoltaic Course Final Project Matlab Model/Goto						
$\overline{\mathbf{v}}$	Icon display: Tag						
^ >	reon display. Tag						
	OK Cancel Help Apply						
	Block Parameters: From1 X						
	From						
	Receive signals from the Goto block with the specified tag. If the tag is defined as 'scoped' in the Goto block, then a Goto Tag Visibility block must be used to define the visibility of the tag. After 'Update Diagram', the block icon displays the selected tag name (local tags are enclosed in brackets, [], and scoped tag names are enclosed in braces, {}).						
	Arguments						
	Goto tag: Y Update Tags						
	Goto source: Photovoltaic Course Final Project Matlab Model/Goto1						
$\overline{\mathbf{v}}$	Icon display: Tag •						
	OK Cancel Help Apply						

2. We add 2 demux block from Simulink library >demux and give the following parameters to it.

Block Parameters: Demux1	×
Demux	
Split vector signals into scalars or smaller vectors. Check 'Bus Selection Mode' to split bus signals.	
Parameters	
Number of outputs:	
2	
Display option: bar	•
Bus selection mode	
OK Cancel Help Apply	
	Demux Split vector signals into scalars or smaller vectors. Check 'Bus Selection Mode' to split bus signals. Parameters Number of outputs: 2 Display option: bar Bus selection mode

3. We add two product block from Simulink library > product and give the following parameters to it.

Block Parameters: Product1	\times
Product	
Multiply or divide inputs. Choose element-wise or matrix product and specify one of the following: a) * or / for each input port. For example, **/* performs the operation 'u1*u2/u3*u4'. b) scalar specifies the number of input ports to be multiplied. If there is only one input port and the Multiplication parameter is set. Element-wise(.*), a single * or / collapses the input signal using the specified operation. However, if the Multiplication parameter is set to Matrix(*), a single * causes the block to output the matrix unchanged and a single / causes the block to output the matrix inverse.	on to
Main Signal Attributes	
Number of inputs:	
2	
Multiplication: Element-wise(.*)	•
OK Cancel Help App	ly

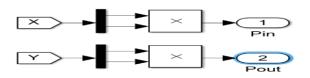
4. To the first product block, we add Outport 1 from Simulink library >outport and give the following parameters to it.

	🚹 Block Parar	neters: Pin				×
	Outport					
	disabled' and executed sub	'Initial output systems. Whe	t' paramete en a condit	ers only app ionally exec	. The 'Output ly to conditior uted subsyste e or set to the	nally m is
	Main Sig	nal Attributes				
	Port number:					
	1					
	Icon display:	Port number				•
→1						
Pin	0		OK	Cancel	Help	Apply

5. To the second product block, we add Outport 1 from Simulink library >outport and give the following parameters to it.

	📔 Block	k Parameters: Po	out			\times
	Outpor	t				
	disable execute	d' and 'Initial ed subsystems d, the output	rt for a subsys output' parame s. When a cond is either held a	eters only appl ditionally execu	y to conditio uted subsyst	nally em is
	Main	Signal Attri	butes			
	Port nu	-				
	2					
	Icon dis	play: Port nu	ımber			-
→ 2						
Pout						
Foul			OK	Cancel	Help	Apply

Step 4: Connect all the above blocks as shown.



4.7.6 DEMUX BLOCK:

Step 1: Add the demux block from Simulink library >demux and give the following parameters to it.

	Block Parameters: Mux	Х
	Mux	
	Multiplex scalar or vector signals.	
	Parameters	_
	Number of inputs:	
	2	
	Display option: bar	•
<u></u> _]→		
	OK Cancel Help Appl	у

4.7.7 SCOPE:

Add scope from Simulink library > Scope.



4.7.8 POWERGUI:

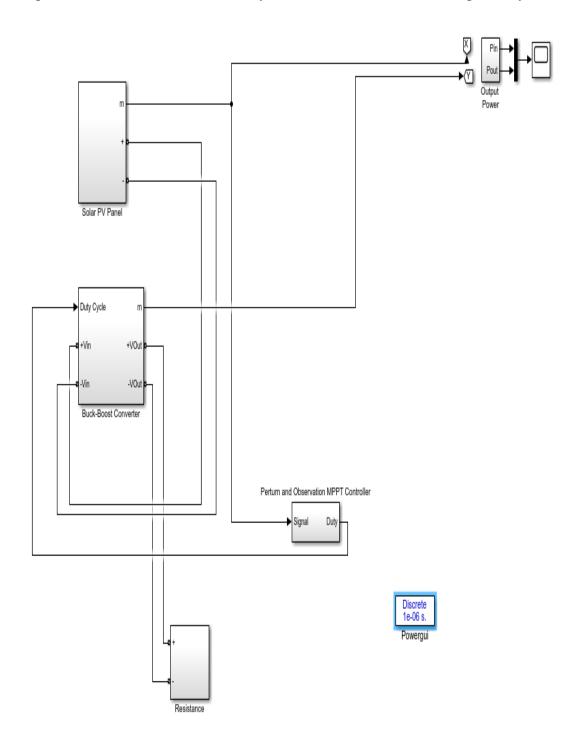
Discrete 1e-06 s. Powergui

Add powergui from Simulink library >powergui and give the following parameters to it.

Solver	Tools	Preferences		
	on type: Dis			
Sample	time (s): 16	-0	 	

Connect the blocks from 4.7.1 to 4.7.9 and thus, finally we obtain the our

equivalent MATLAB model of PV system with MPPT Controller respectively.



MATLAB model of PV system with MPPT Controller

PART 5

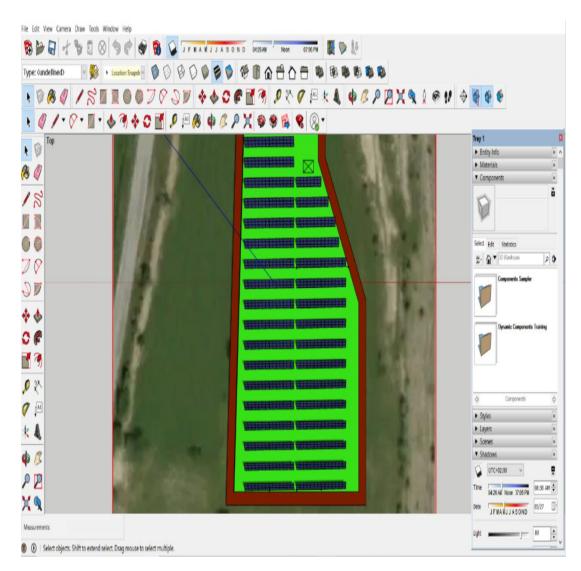
SUMMARY

5.1 RESULTS AND DISCUSSION

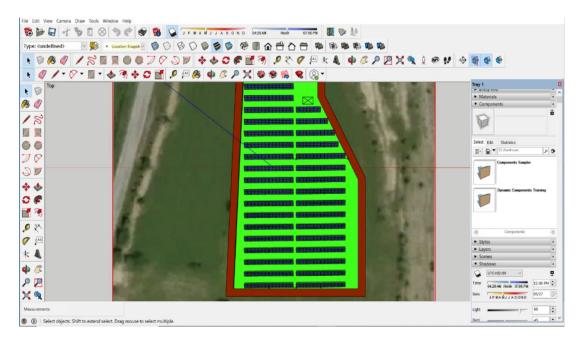
5.5.1 RESULT OF SKETCHUP MODEL OF GROUND PHOTOVOLTAIC PANEL SYSTEM.

A) For our designed ground photovoltaic system using the Sketch up software the solar panel exposure and the shadow effect at Safranbolu (Besides Bartin Karabuk Yolu Road) on 27 May 2020 at 08:30 AM, 12:00 PM and 03:15 PM is as shown below.

At 08:30 AM,



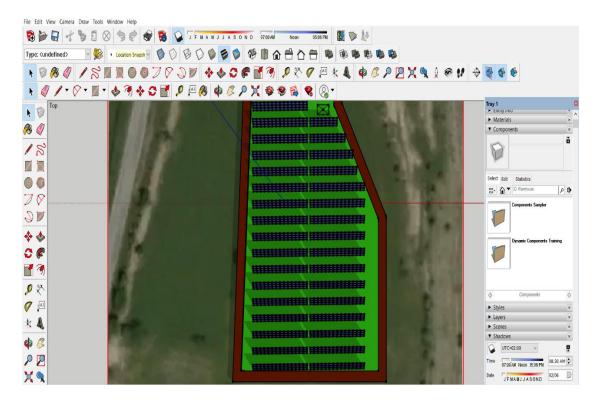
At 12: 00 PM,



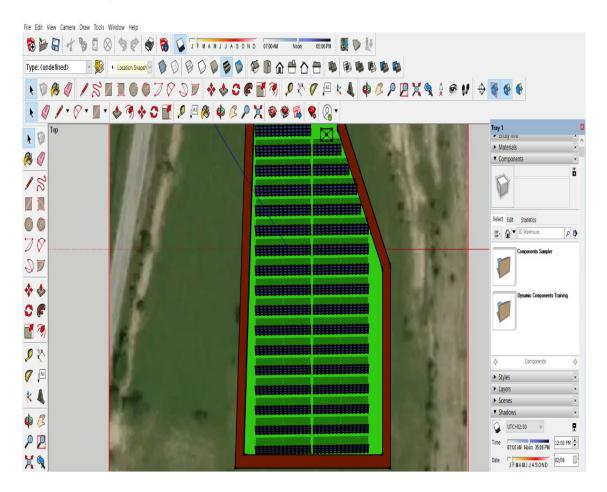
At 03:15 PM,

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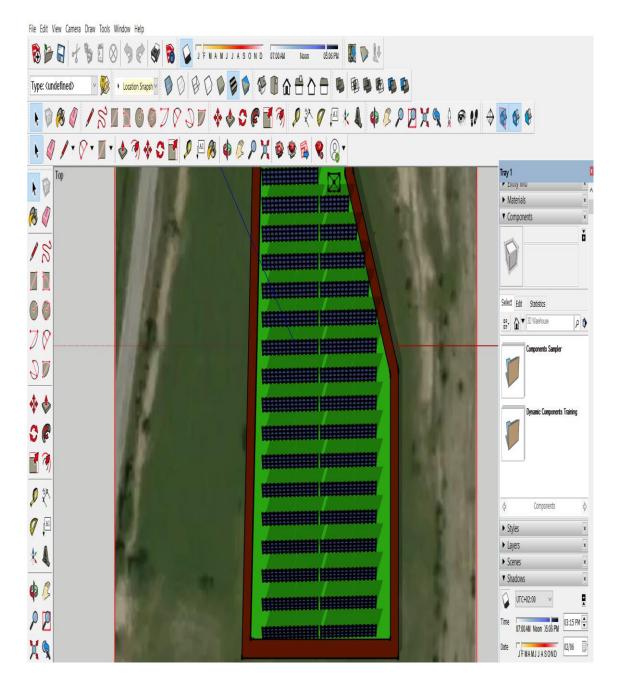
A) For our designed ground photovoltaic system using the Sketch up software the solar panel exposure and the shadow effect at Safranbolu (Besides Bartin Karabuk Yolu Road) on 6 February 2020 at 08:30 AM, 12:00 PM and 03:15 PM is as shown below. At 08:30 AM,



At 12:00 PM,

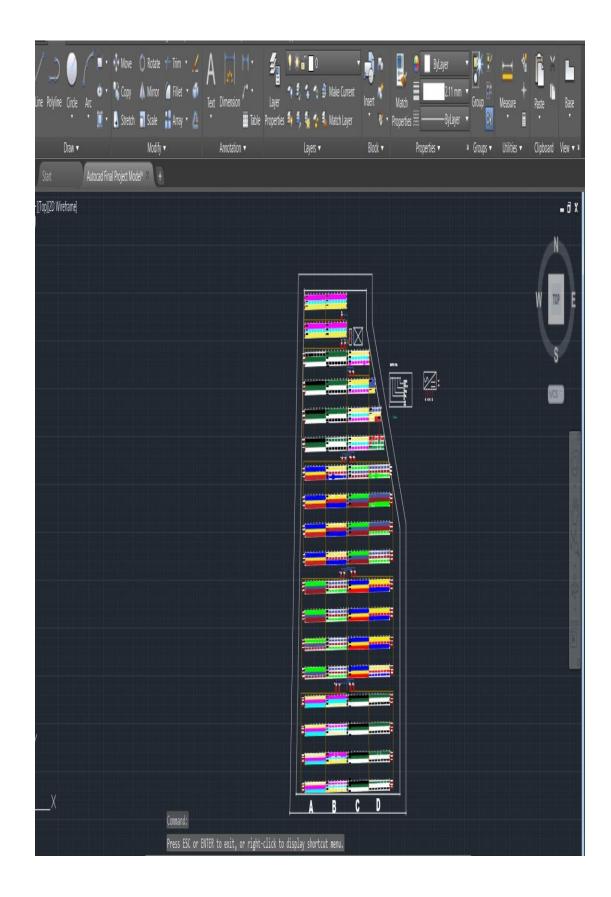


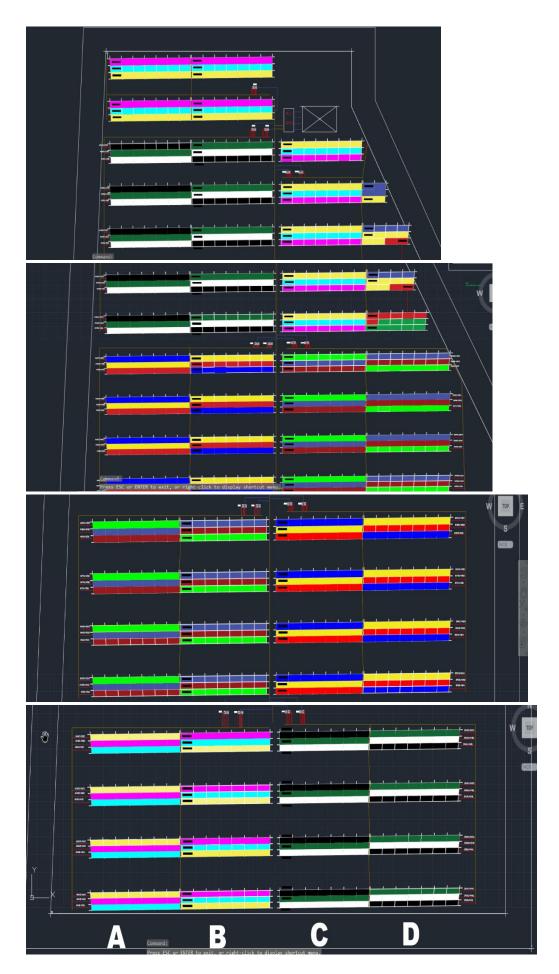
At 03:15 PM,



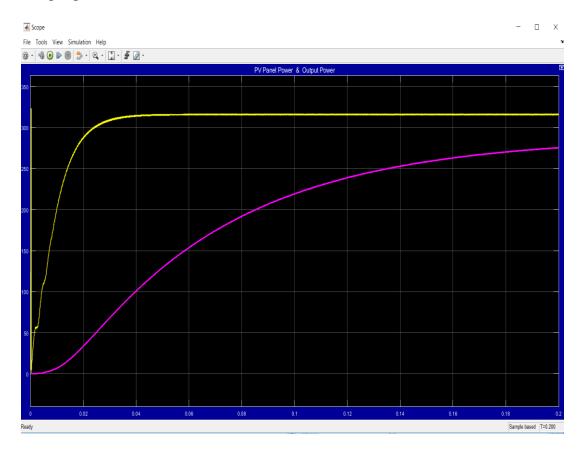
5.5.2 RESULT OF AUTOCAD MODEL OF GROUND PHOTOVOLTAIC PANEL SYSTEM.

For our designed ground photovoltaic system using the Sketch up software at Safranbolu (Besides Bartin Karabuk Yolu Road) we have successfully designed the overall electrical interconnection among the various components such as Solar panel, inverters and the AC Box. The overall electrical interconnection of our Ground photovoltaic panel system is as shown below.





5.5.3 SIMULATION RESULT OF MATLAB MODEL OF PHOTOVOLTAIC SYSTEM WITH MAXIMUMPOWER POINT TRACKING CONTROLLER.



Output power V/s Time Characteristics

In our Solar PV Module,

Voc = 37.5 V, Isc= 8.63 A

Thus, the Output Power P of Solar PV Module= Voc X Isc = $37.5 \times 8.63 = 323.62 \text{ W}$, with respect to time which is represented by the Yellow line in the above simulation.

The Output power of the Solar PV Module with MPPT controller w.r.t time is approximately 275 W which is represented by Pink line in the above simulation.

5.2 CONCLUSION

Worldwide environmental change is a developing concern. Sun oriented force lessens dependence on petroleum products, for example, oil, coal and gaseous petrol. At the point when petroleum products are utilized to make power, they produce hurtful gas outflows that influence the wellbeing of air, water and soil. Interestingly, sun based vitality creates no contamination. The sun's capacity offers a boundless wellspring of vitality that doesn't strip the scene or damage the ozone layer. The U.S. Natural Protection Agency prescribes changing to sustainable power sources since these frameworks discharge lower carbon emanations. Sun based vitality frameworks speak to an interest later on for earth, moderating non-reasonable vitality sources and ensuring the earth for the people to come. Thus, our thesis presents a complete design of the Ground photovoltaic system and also discusses electrical interconnection of the designed model so that Solar power can be empowered over other energy sources. It gives an idea for researchers based on the design aspects and simplifies the electrical interconnection to establish a solar plant in Safranbolu, Turkey. Also, we have simulated the Photovoltaic Module with MPP tracking controller and obtained the Simulation results of power output of the Photovoltaic module.

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RESUME

Sumair Mashraf was born in Shankarpally, Hyderabad (INDIA) in 1996 and graduated first and elementary education in this city. He accomplished high school education in Kendriya Vidyalaya School, after which, he began undergraduate program in Gokaraju Rangaraju Institute of Engineering and Technology, Department of Electrical and Electronics in 2018. Then in 2018, he started studying in Karabük University, Department of Electrical and Electronics Engineering to complete M. Sc. education, where he has been still studying.

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