

DEVICE STRATEGIES TO IMPROVE GRID CONNECTED TYPICAL 10KW PHOTOVOLTAIC SYSTEM

Sunil Singh¹,Lakhan Singh²

¹Assistant Professor Department of Mathematics

²Assistant Professor Department of Electrical Engineering

Abstract This paper presents a modelling method of photovoltaic systems (SPR305E-WHT) and an implementation and comparison of three MPPT techniques ,fuzzy logic control, incremental conductance ,perturb observe method for maximum power point tracking (MPPT) algorithm. The method is used to study the influence of rapidly changing irradiance level concerning performance of 10KW photovoltaic systems. A simple circuit model of the boost converter connected to the photovoltaic systems is used to easily simulate the incremental conductance MPPT method. The model has been implemented in MATLAB / Simulink 2013 . The simulation results are presented and analysed to validate that the proposed simulation model is effective for MPPT control of the photovoltaic systems at rapidly changing irradiation condition.

Keywords: photovoltaic array (SPR305E-WHT), boost converter, Maximum Power Point Tracking techniques, R-L filter, multilevel inverter, RLC load.

INTRODUCTION Nowadays the fossil fuel has been consumed increasingly. Solar energy, as one kind of clean and renewable energy, because of its rich reserves of raw materials-silicon, a decline in the cost of production and improving of the conversion efficiency, has prompted the photovoltaic power generation to become an important role in the future development. Whether from the point of environmental protection or solving the energy problem, the development and utilization of solar energy is of great strategic significance [1].

As we know, the electric energy can't be stored on a large scale, and islanding phenomenon may occur whenever the power system breaks down, which requires that the photovoltaic power system store electrical energy in normal circumstances and release it in case of islanding status, thus maintaining the voltage and frequency stable. So it's necessary to add storage device to the photovoltaic grid-connected system. Energy storage device introduced into the system can realize management of demand side, eliminate valley-to-peak difference between day and night and smooth load [1].

BASIC PHOTOVOLTAIC CELL The basic structure of solar cells is to use a p-type semiconductor with a small quantity of boron atoms as the substrate. Phosphorous atoms are then added to the substrate using high-temperature diffusion method in order to form the p-n junction. In the p-n junction, holes and electrons

will be rearranged to form a potential barrier in order to prevent the motion of electrical charges. When the p-n structure is irradiated by sunlight, the energy supplied by photons will excite the electrons in the structure to produce hole-electron pairs. These electrical charges are separated by the potential barrier at the p-n junction[4]. The electrons will move towards the n-type semiconductor and the holes will move towards the p-type semiconductor at the same time. If the n-type and p-type semiconductors of a solar cell are connected with an external circuit at this moment, the electrons in the n-type semiconductor will move to the other side through the external circuit to combine with the holes in the p-type semiconductor.

The photovoltaic (PV) provide one of the most efficient ways of producing energy, with real perspectives in the future, considering the actual situation of the resources around the world. It becomes a real problem the fact that we have insufficient supplies of this kind of resources for insuring the world's needs. Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP[5]. The principle of maximum power point tracking (MPPT) is to place a convertor between the load and the PV array. It regulates the array output voltage (or current) so that the maximum available power is extracted [5]. A power converter is necessary to adjust the energy flow from the PV array to the load.

MATHEMATICAL DESCRIPTION OF PHOTOVOLTAIC CELL General mathematical description of I-V output characteristics for a PV cell has been studied for over the past four decades. Such an equivalent circuit-based model is mainly used for the MPPT technologies. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the current flow, is shown in Fig.1 [6]. The voltage-current characteristic equation of a solar cell is given a

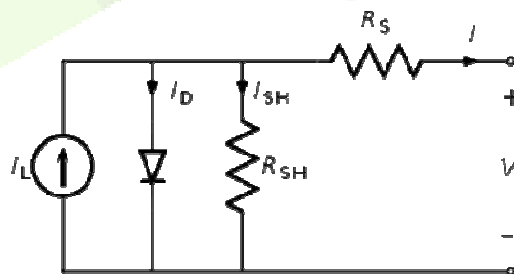


Figure:1 Photovoltaic equivalent cells

from the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode,

minus that which flows through the shunt resistor:

$$I = I_L - I_D - I_{SH} \quad (1.1)$$

where

I = output current (ampere)

I_L = photogenerated current (ampere)

I_D = diode current (ampere)

I_{SH} = shunt current (ampere).

The current through these elements is governed by the voltage across them:

$$V_j = V + IR_S \quad (1.2)$$

where

V_j = voltage across both diode and resistor R_{SH} (volt)

V = voltage across the output terminals (volt)

I = output current (ampere)

R_S = series resistance (Ω).

By the Shockley diode equation, the current diverted through the diode is:

$$I_D = [\exp \frac{V_j}{nkt} - 1] \quad (1.3)$$

where

I_0 = reverse saturation current (ampere)

n = diode ideality factor (1 for an ideal diode)

q = elementary charge

k = Boltzmann's constant

T = absolute temperature

At 25°C, $KT \approx 0.0259$ volt

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_j}{R_{SH}} \quad (1.4)$$

Where

R_{SH} = shunt resistance (Ω).

SIMULINK MODEL OF PV SYSTEM WITH MPPT solarpanel connected to resistive load through a boostconverter withMPPT controller.

BlockName=gcb;

Type=1;

$k= 1.3806e-23$; % Boltzman constant ($J.K^{-1}$)

$q=1.6022e-19$; % electron charge (C)

$T=273+25$;

$Pmp=305$

$nCells=96$;

$Voc=64.20$;

$Isc=5.96$;

$Vm=72.9$;

$Im=5.58$;

$Rs=0.037998$;

$Rp=993.51$;

$Isat=1.6753e-08$;

$Iph=5.9602$;

$Qd=1.3$;

$Voc_TrK = 85.7 / nCells$;

$TrK=298$

```
n = 1.3;
Isc1 = Isat * (1 + (Vm * (Iph - Im)));
% G( G=1KW/m2)
Iph2 = Qd * Isc1;
Vt_TrK = nCells * k * T / q;
b = Rp * q / (nCells * k);
Ir_TrK = Isc / (exp(Voc_TrK / Vt_TrK) - 1);
Ir = Ir_TrK * (T / TrK)^(3/n) * exp(-b * (1 / T - 1 / TrK));
% Take dV/dI @ Voc from I-V curve of datasheet
dVdI_Voc = -1.0/nCells;
Xv = Ir_TrK / Vt_TrK * exp(Voc / Vt_TrK);
Rs = - dVdI_Voc - 1/Xv;
Vt_Ta = n * k * T / q;
% Ia = Iph - Ir * (exp((Vc + Ia * Rs) / Vt_Ta) - 1)
% f(Ia) = Iph - Ia - Ir * (exp((Vc + Ia * Rs) / Vt_Ta) - 1) = 0
% Solve for Ia by Newton's method: Ia2 = Ia1 - f(Ia1)/f'(Ia1)

VT=k*T/q*nCells*Qd;

set_param(BlockName,'Ncell',num2str(nCells));
str=sprintf([' %g %g %g %g '],Voc,Isc,Vm,Im);
set_param(BlockName,'ModuleParameter',str);
str=sprintf([' %g %g %g %g %g '],Rs,Rp,Isat,Iph, Qd);
set_param(BlockName,'ModelParameters',str)

Iph_array=Iph*Npar;
Isat_array=Isat*Npar;
```

```
VT_array=VT*Nser;
Rs_array=Rs*Nser/Npar;
Rp_array=Rp*Nser/Npar;
%
%% Plot I-V & P-V characteristics of one module
%
ifPlotVI_module | PlotVI_array
assignin('base','Voc',Voc);
assignin('base','Isc',Isc);
assignin('base','Rs',Rs);
assignin('base','Rp',Rp);
assignin('base','Isat',Isat);
assignin('base','VT',VT);
ifPlotVI_module,
F1=figure('Name','I-V and P-V characteristics of one module at 25 deg.C');
end
ifPlotVI_array ,
F2=figure('Name','I-V and P-V characteristics of array at 25 deg.C');
end

load_system('PV_model_Param');

forksun=1:-0.25:0.25
assignin('base','Iph',Iph*ksun)
sim('PV_model_Param');
n=find(I_PV>=0);

I_PV=I_PV(n);
V_PV=V_PV(n);
```

```
P_PV=V_PV.*I_PV;
```

```
ifPlotVI_module
```

```
figure(F1);
```

```
subplot(211)
```

```
ifksun==1
```

```
plot(V_PV,I_PV,'b',[0 VmVoc], [IscIm 0],'ro')
```

```
% text(Voc/15,Isc*1.1,")
```

```
holdon
```

```
grid
```

```
else
```

```
plot(V_PV,I_PV,'--m')
```

```
% text(Voc/15, Isc*(ksun+0.1) , sprintf('%g kW/m^2',ksun))
```

```
end
```

```
subplot(212)
```

```
ifksun==1
```

```
plot(V_PV,P_PV,'b',[0 VmVoc], [0 Im*Vm 0],'ro')
```

```
% text(Vm*1.02,Vm*Im,'1 kW/m^2')
```

```
holdon
```

```
grid
```

```
else
```

```
n= find(P_PV==max(P_PV));
```

```
plot(V_PV,P_PV,'--m', V_PV(n) , P_PV(n),'mo')
```

```
% text(Vm*1.02, Vm*Im*ksun, sprintf('%g kW/m^2',ksun))
```

```
end
```

```
subplot(211)
```

```
ylabel('Current (A)')
```

```
xlabel('Voltage (V)')
```

```
% title(sprintf('Module type: %s',SolarModuleSpec(Type).Desc))
```

```
axis_xy=axis;
```

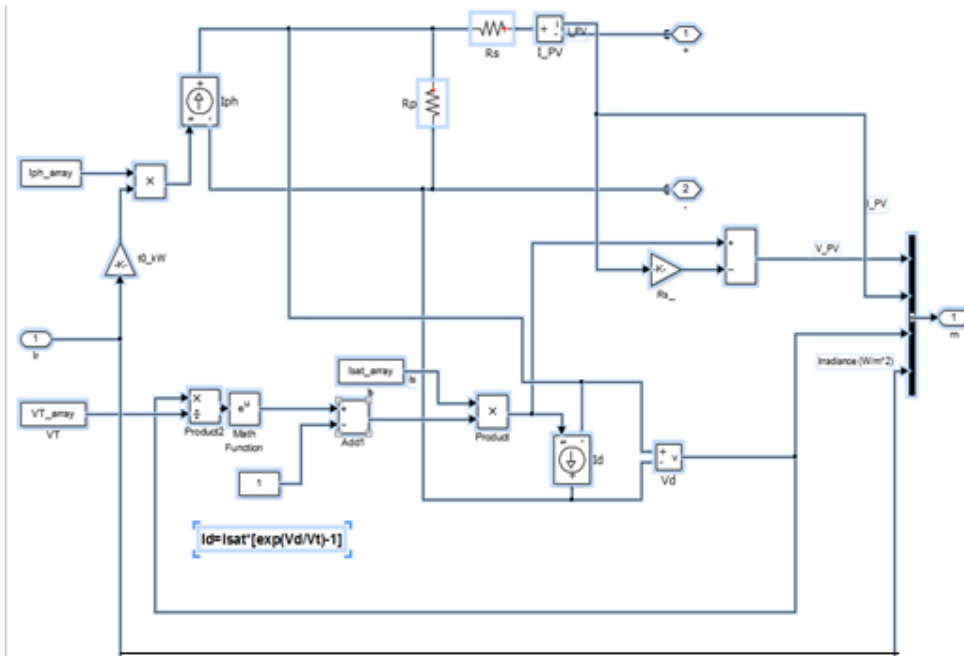
```
axis_xy(4)=Isc*1.2;
axis(axis_xy);
subplot(212)
ylabel('Power (W)')
xlabel('Voltage (V)')
axis_xy=axis;
axis_xy(4)=Vm*Im*1.2;
axis(axis_xy);
set_param(BlockName,'PlotVI_module','off')
end

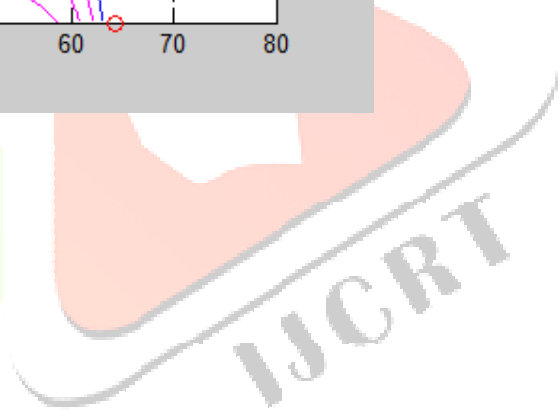
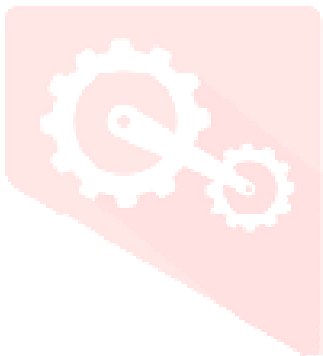
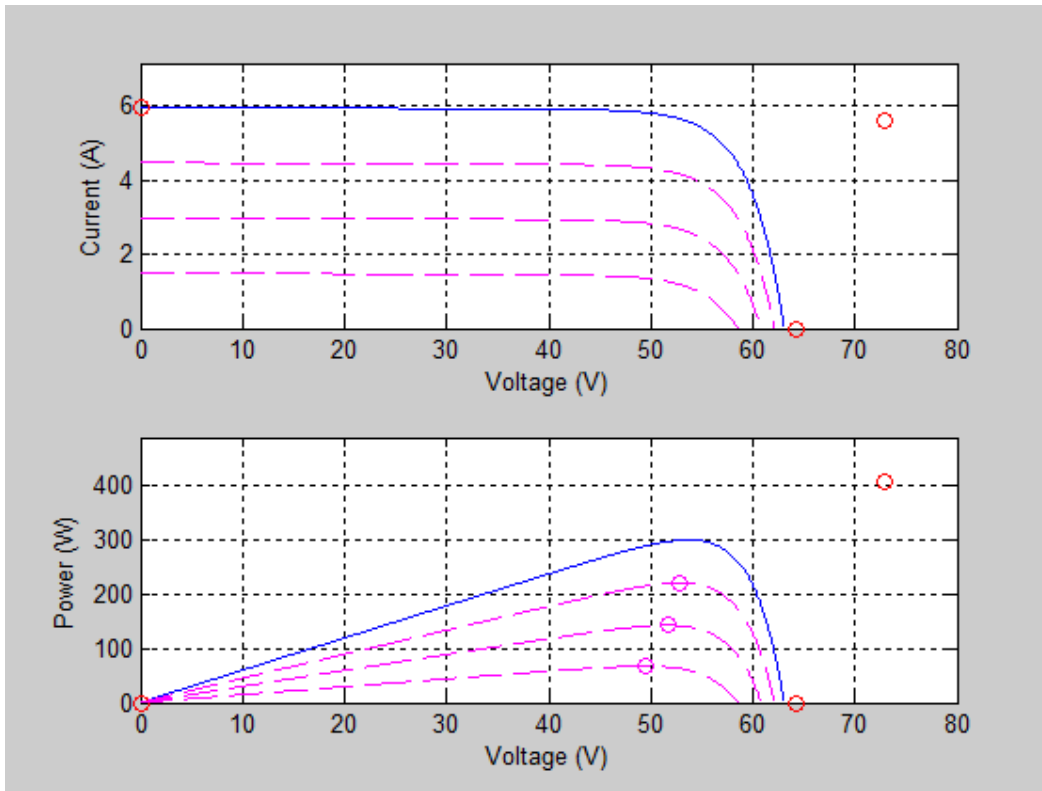
ifPlotVI_array
figure(F2);
subplot(211)
ifksun==1
plot(V_PV*Nser,I_PV*Npar,'b',[0 VmVoc]*Nser, [IscIm 0]*Npar,'ro')
% text(Voc/15*Nser,Isc*1.1*Npar,")
holdon
grid
else
plot(V_PV*Nser,I_PV*Npar,'--m')
%text(Voc*Nser/15, Isc*Npar*(ksun+0.1) , sprintf(",ksun))
end

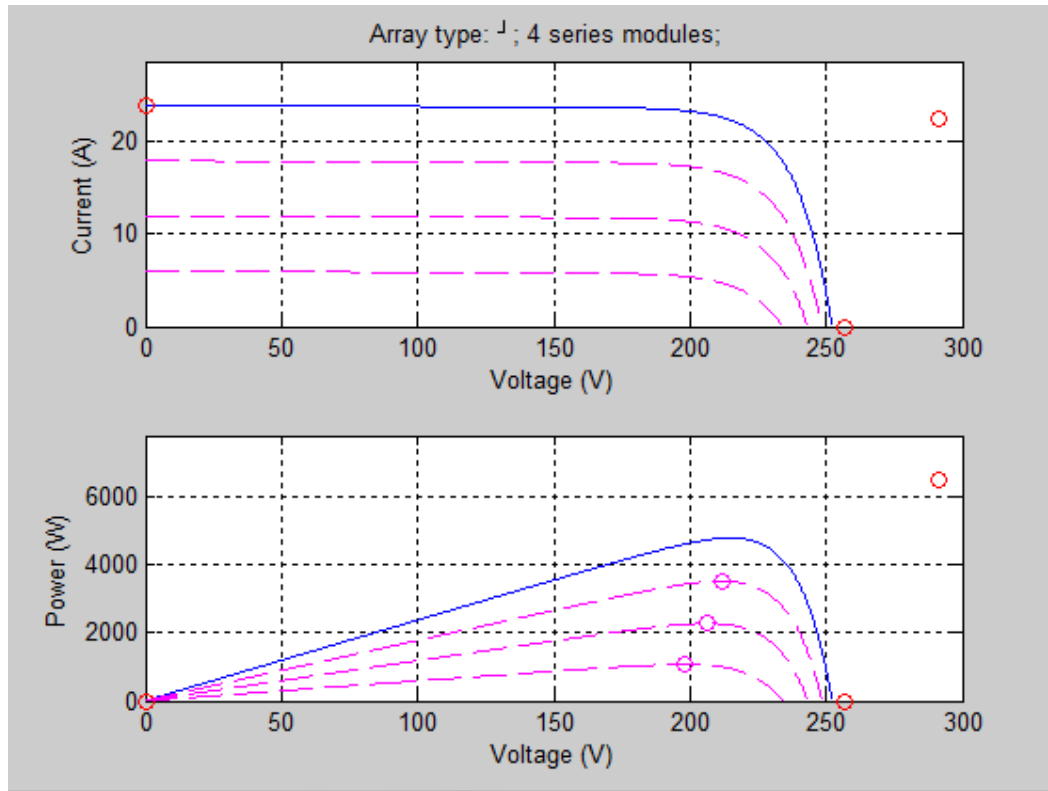
subplot(212)
ifksun==1
plot(V_PV*Nser,P_PV*Nser*Npar,'b',[0 VmVoc]*Nser, [0 Im*Vm 0]*Nser*Npar,'ro')
% text(Vm*Nser*1.02,Vm*Im*Nser*Npar,")
holdon
grid
```



```
else
n= find(P_PV==max(P_PV));
plot(V_PV*Nser,P_PV*Nser*Npar,'--m', V_PV(n)*Nser , P_PV(n)*Nser*Npar,'mo')
% text(Vm*Nser*1.02, Vm*Im*Nser*Npar*ksun, sprintf(",ksun"))
end
subplot(211)
ylabel('Current (A)')
xlabel('Voltage (V)')
title(sprintf('Array type: %s; %d series modules; %d parallel strings',Nser,Npar));
axis_xy=axis;
axis_xy(4)=Isc*Npar*1.2;
axis(axis_xy);
subplot(212)
ylabel('Power (W)')
xlabel('Voltage (V)')
xis_xy=axis;
axis_xy(4)=Vm*Im*Nser*Npar*1.2;
axis(axis_xy);
set_param(BlockName,'PlotVI_array', 'off')
end
end
end
```







CHOICE OF MPPT TECHNIQUE photovoltaic array (SPR 305E-WHT) is an unregulated dc power source, which has to be properly conditioned in order to interface it to the grid. The dc/dc converter is present at the PV array output for MPPT purposes, i.e. for extracting the maximum available power for a given insolation level. The step-down dc/dc converter (boost converter) is used as a dc transformer which can match the array optimum load by changing its switching duty ratio.

1. Implementation complexity
2. Sensors required
3. Ability to detect multiple local maxima
4. Cost
5. Application

6. Response time

MAXIMUM POWERPOINT TECHNIQUES

[1] Perturb & observe method

2] Incremental Conductance

[3] Fuzzy Logic Control

(1) **1.5.1 Perturb & observe method** Hill climbing involves a perturbation in the duty ratio of the power converter; P&O involves a perturbation in the operating voltage of the PV array. In the case of a PV array connected to a power converter, perturbing the duty ratio of power converter perturbs the PV array current, and consequently perturbs the PV array voltage; hill climbing and P&O methods are two different ways to perform the same fundamental method.

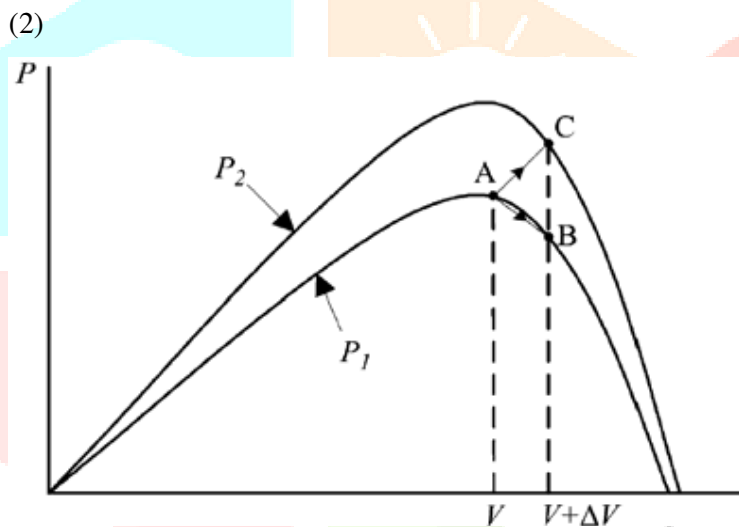


Figure-4. Divergence of hill climbing/P&O from MPP

Incremental Conductance The incremental conductance method is based on the fact that the slope of the PV array power curves at the MPP is zero, positive on the left, and negative on the right of the MPP. figure. the mathematical relations are shown below

$$(3) \frac{dP}{dV} = 0 \tag{1.6}$$

$$(4) \frac{dP}{dV} > 0 \text{ left of MPP} \tag{1.7}$$

$$(5) \frac{dP}{dV} < 0 \text{ right of MPP} \tag{1.8}$$

$$(6) \text{ SINCE } \frac{dP}{dV} = \frac{d(IV)}{dV} = 1 + V \left(\frac{dI}{dV} \right) \tag{1.9}$$

$$(7) = -I/V = (dI/dV) \tag{1.10}$$

(8) The MPP can thus be tracked by comparing the instantaneous conductance term (I/V) with the incremental conductance term (dI/dV)

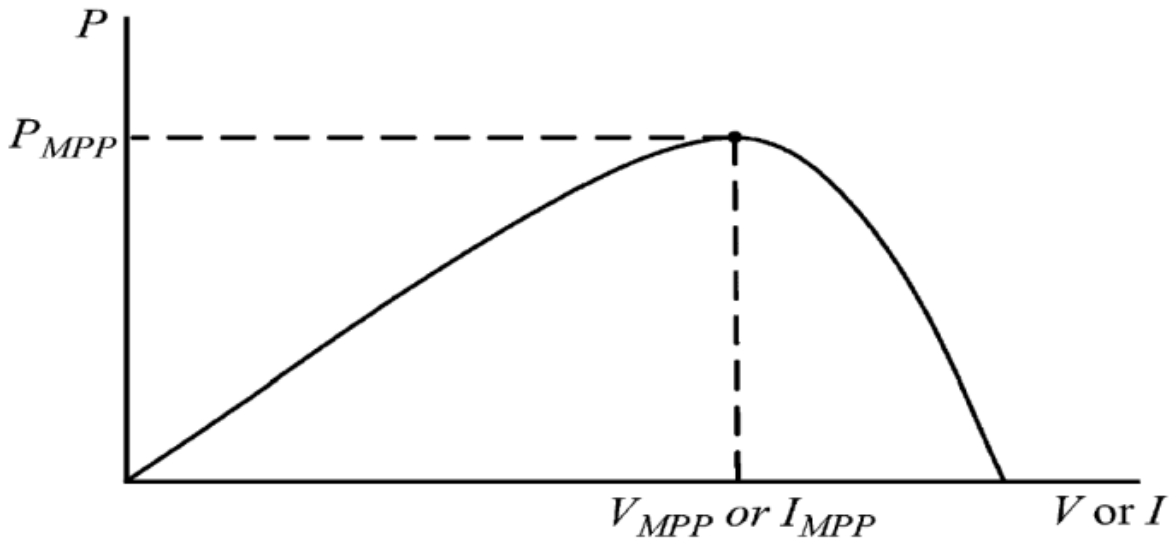


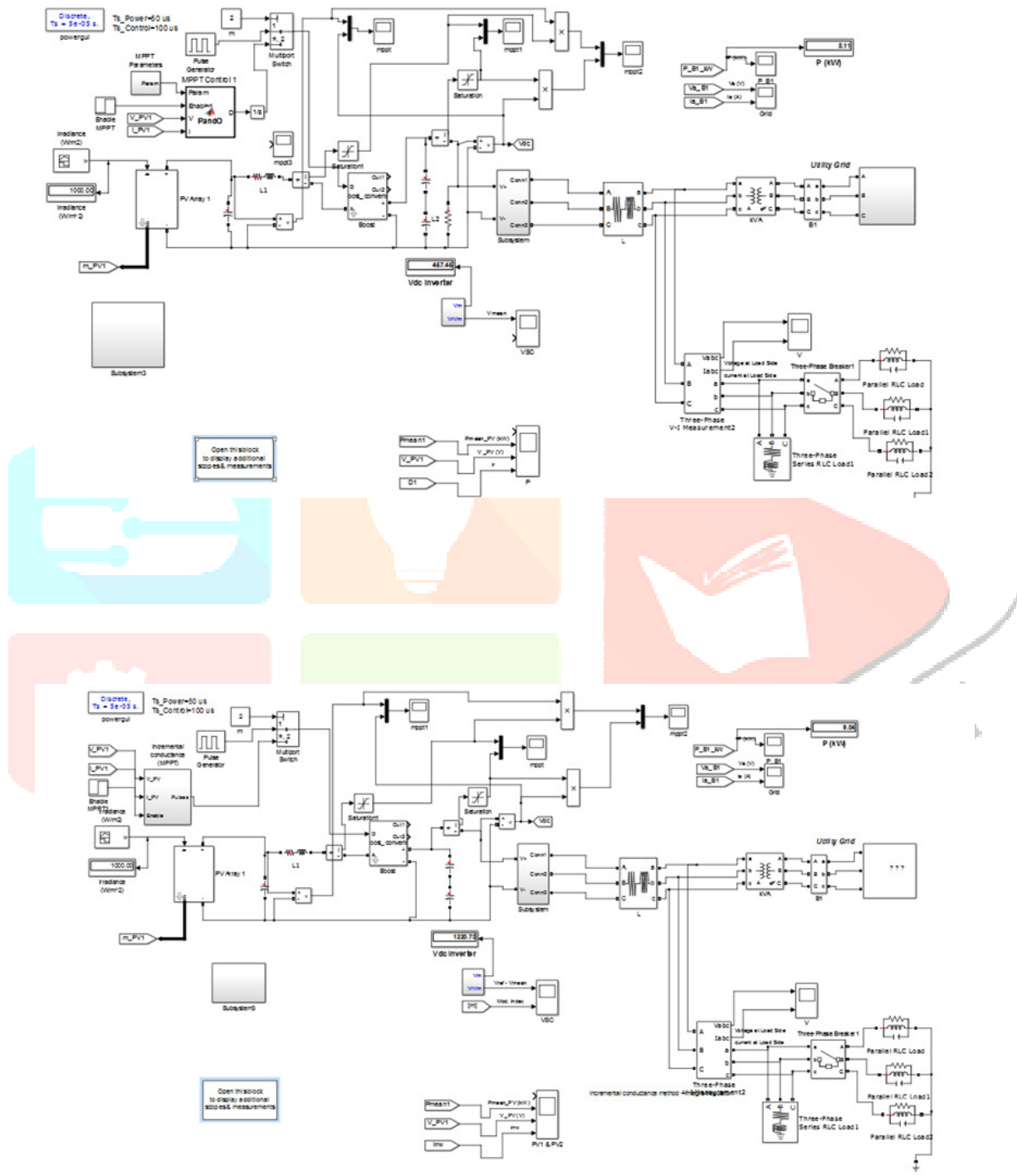
Figure-5 Characteristic photovoltaic Array power curve

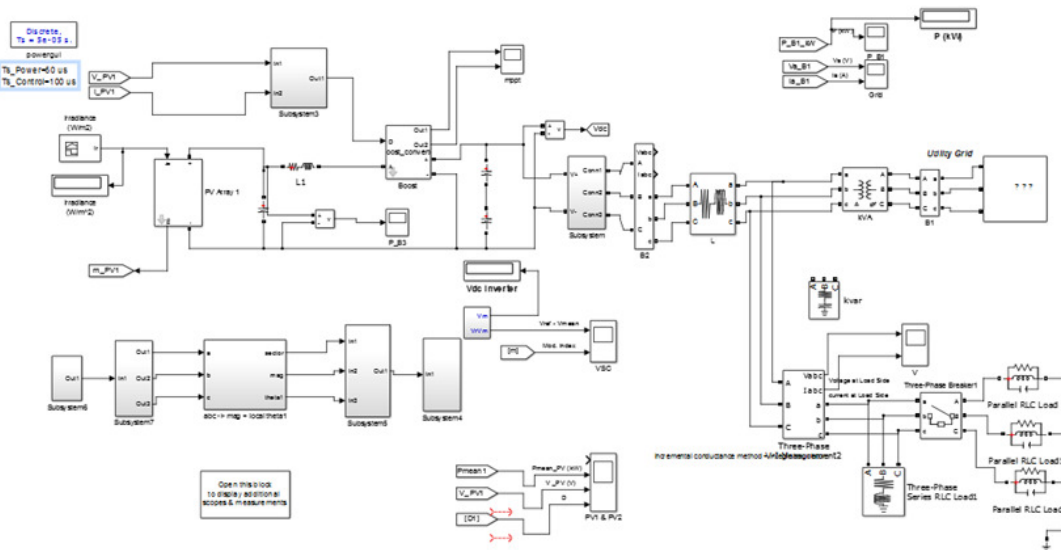
Fuzzy Logic Control Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. Fuzzy logic control generally consists of three stages: fuzzification, rule base lookup table, and defuzzification. During fuzzification, numerical input variables are converted into linguistic variables based on a membership function. In this case, five fuzzy levels are used: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big) [3]. The inputs to a MPPT fuzzy logic controller are usually an error E and a change in error ΔE . The user has the flexibility of choosing how to compute E and ΔE . Since dP/dV vanishes at the MPP [3]. By calculate the following

$$E(n) = [P(n) - p(n-1)]/[V(n) - V(n-1)] \quad (1.11)$$

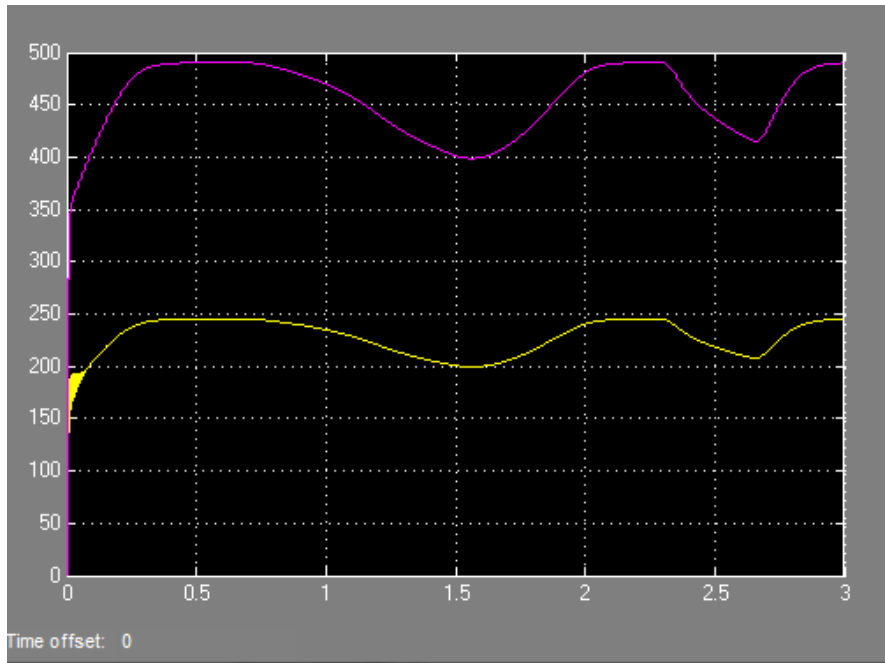
$$\Delta E(n) = E(n) - E(n-1)$$

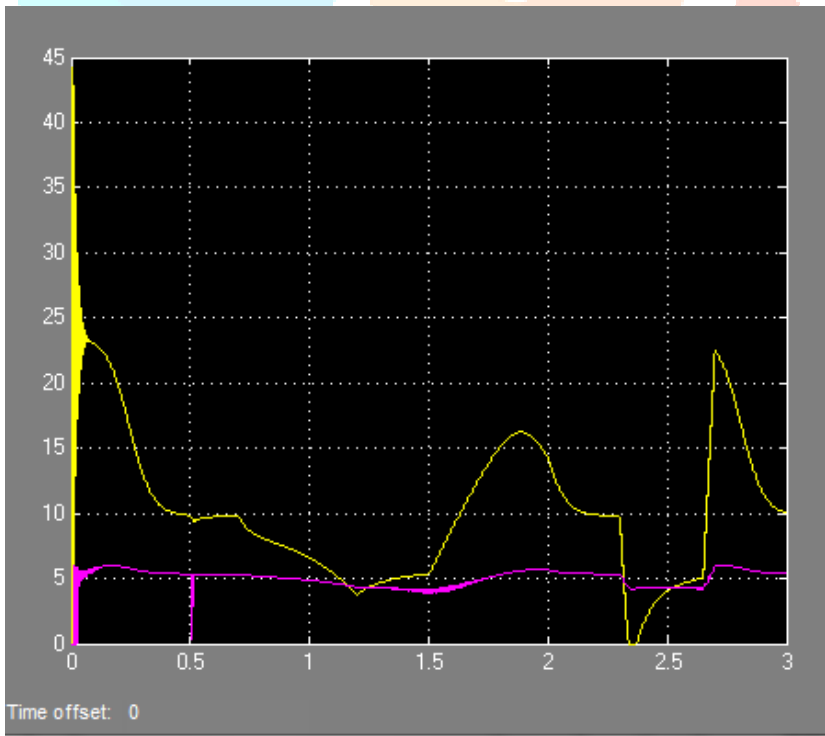
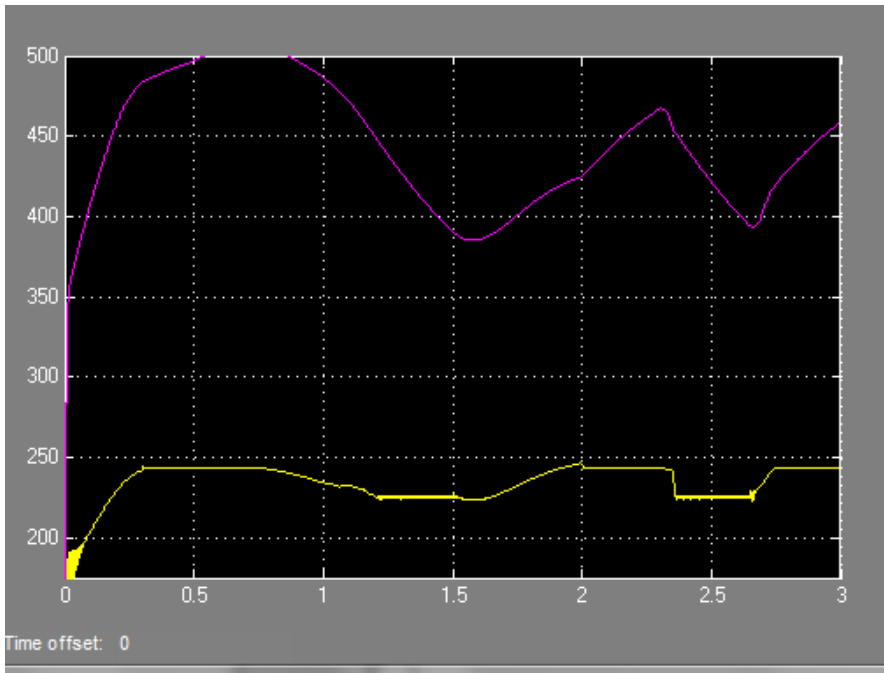
MATLAB SIMULINK MODEL OF 10KW PHOTOVOLTAIC (SPR305E-WHT)

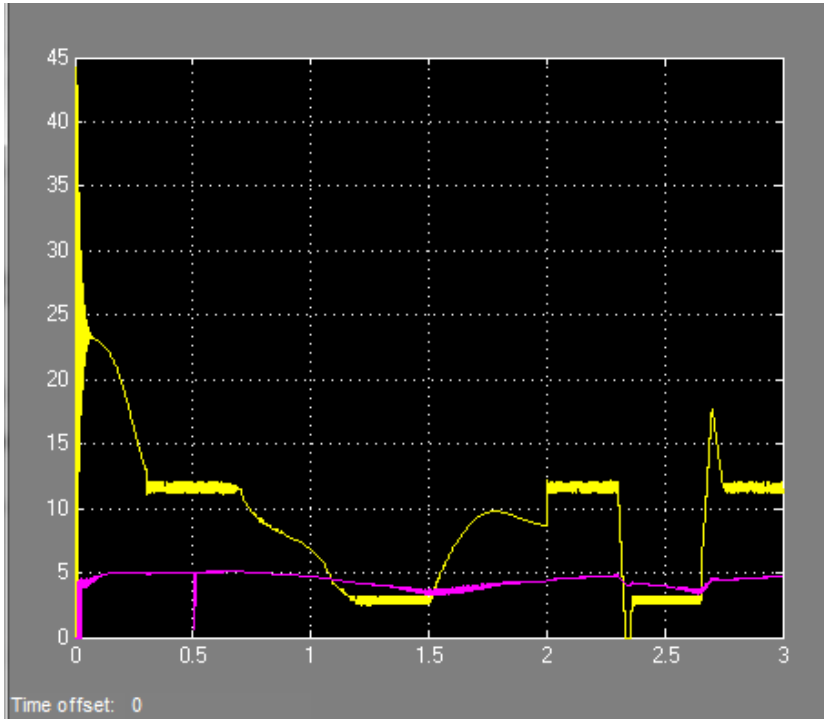


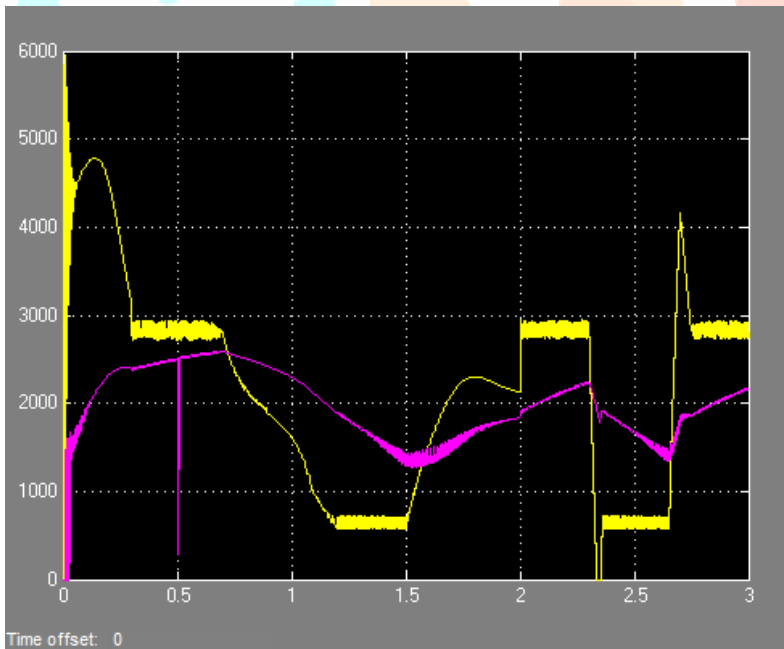
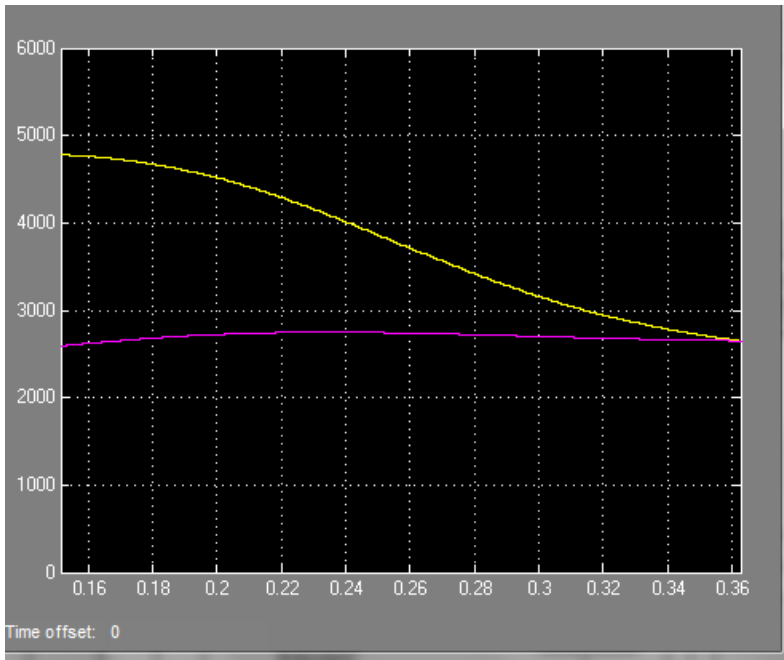


RESULT ANALYSIS OF 10 KW CRITICAL PV SYSTEM IN DIFFERENT MAXIMUM POWER POINT TRACKING

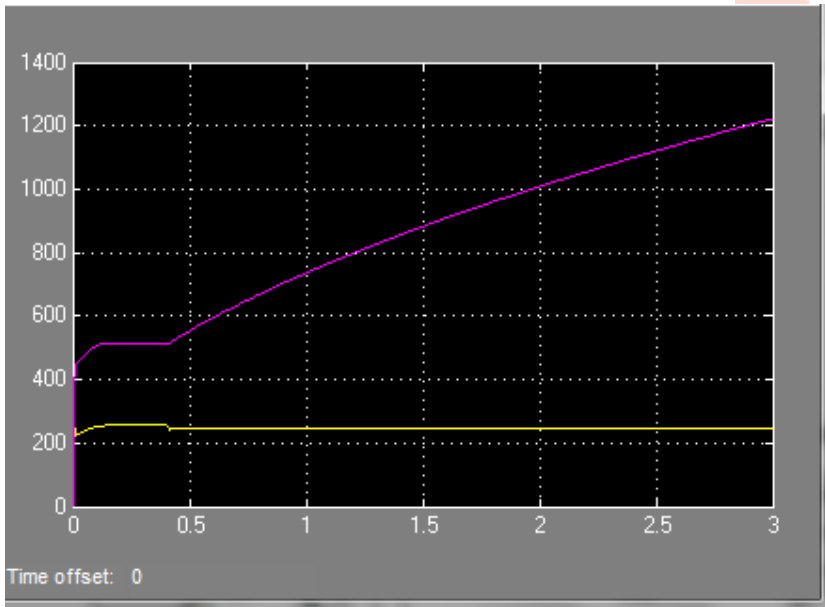
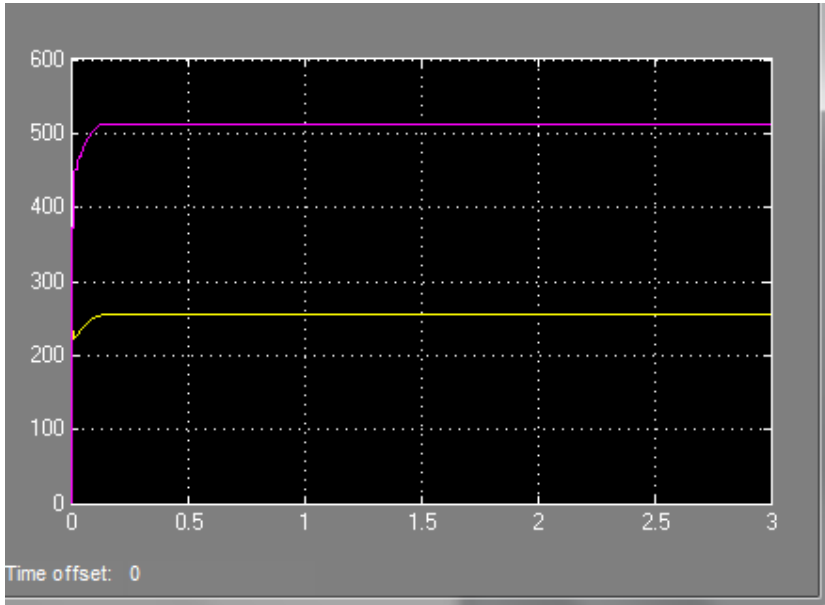


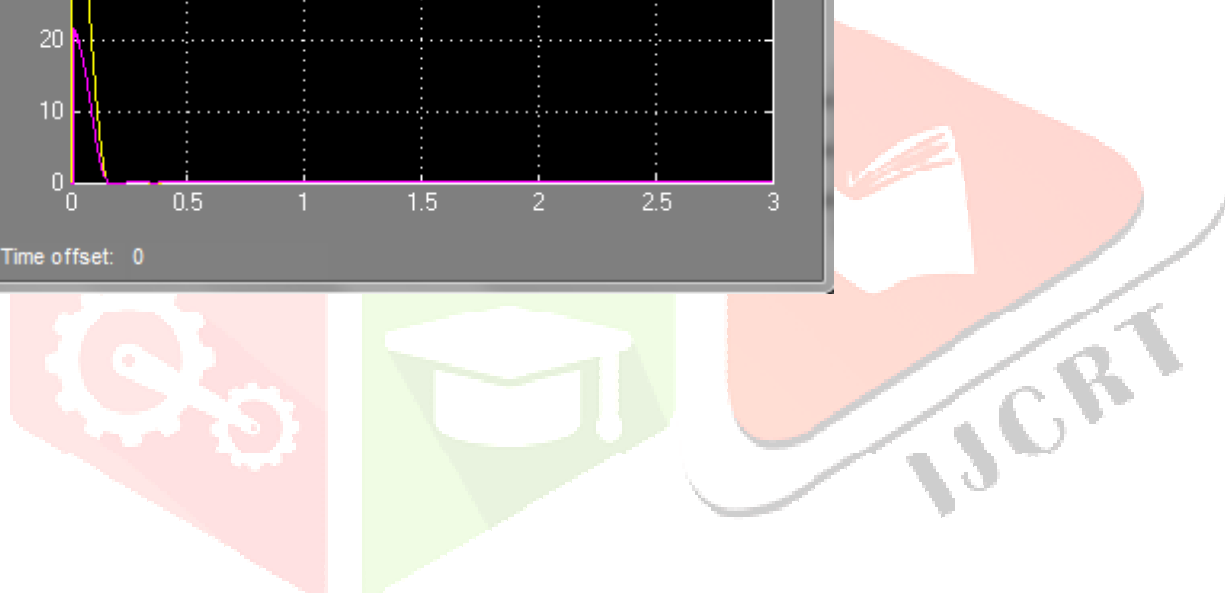
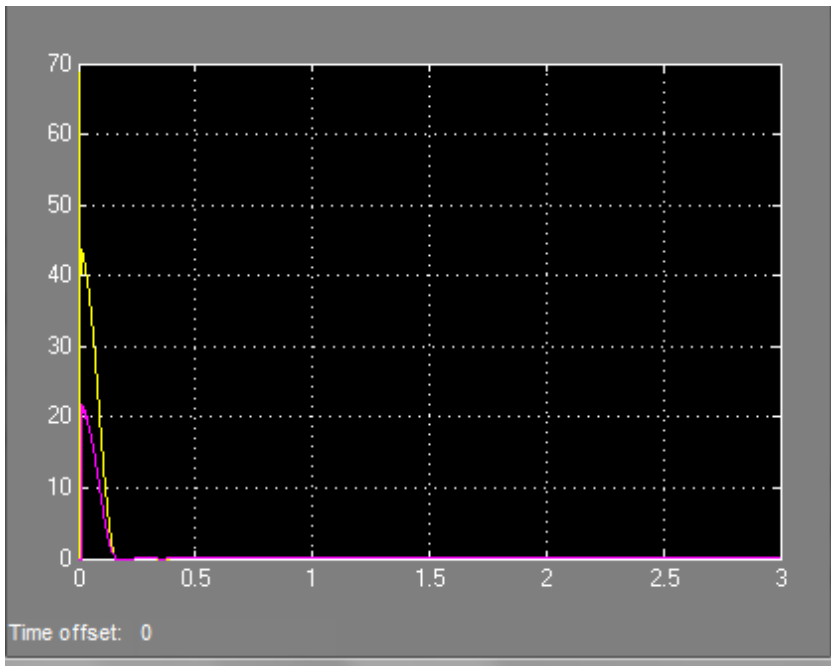


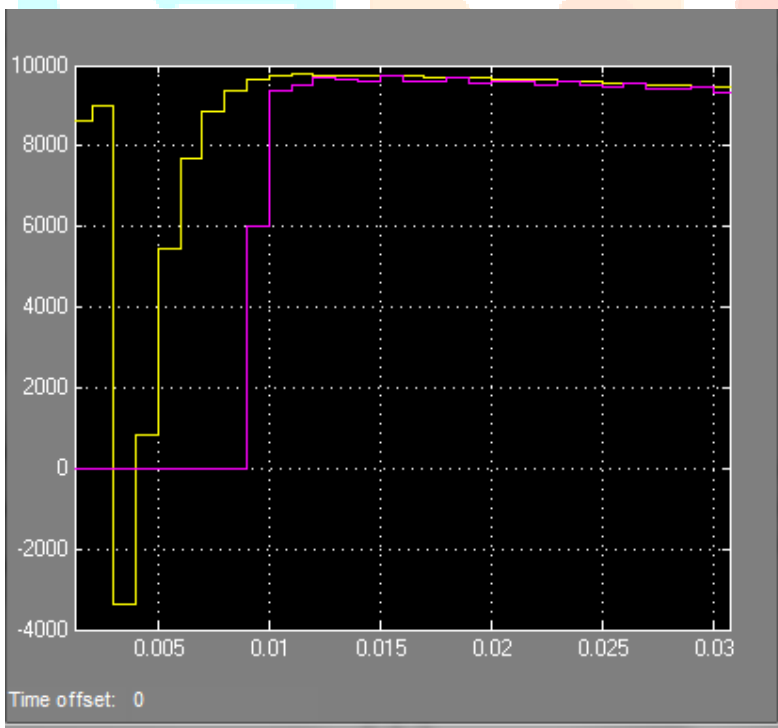
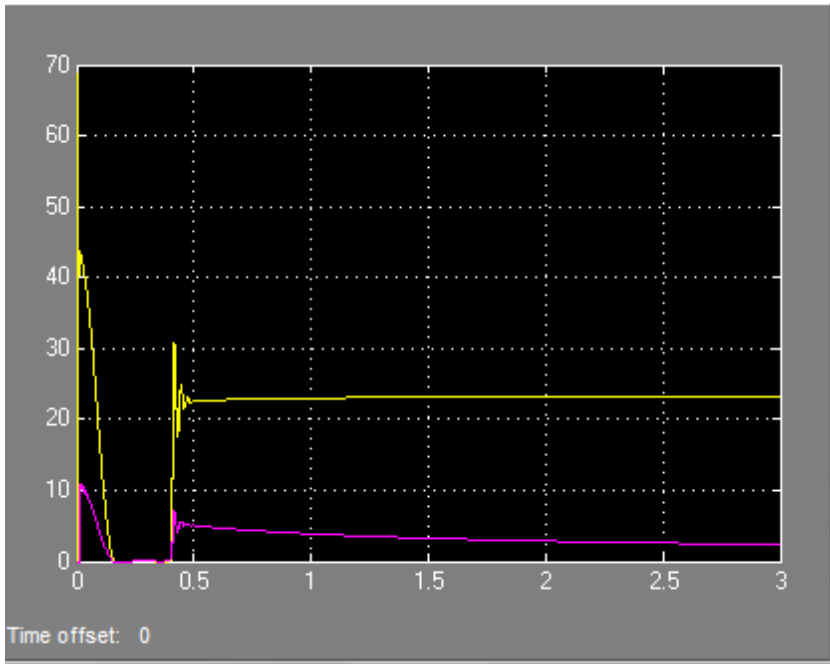


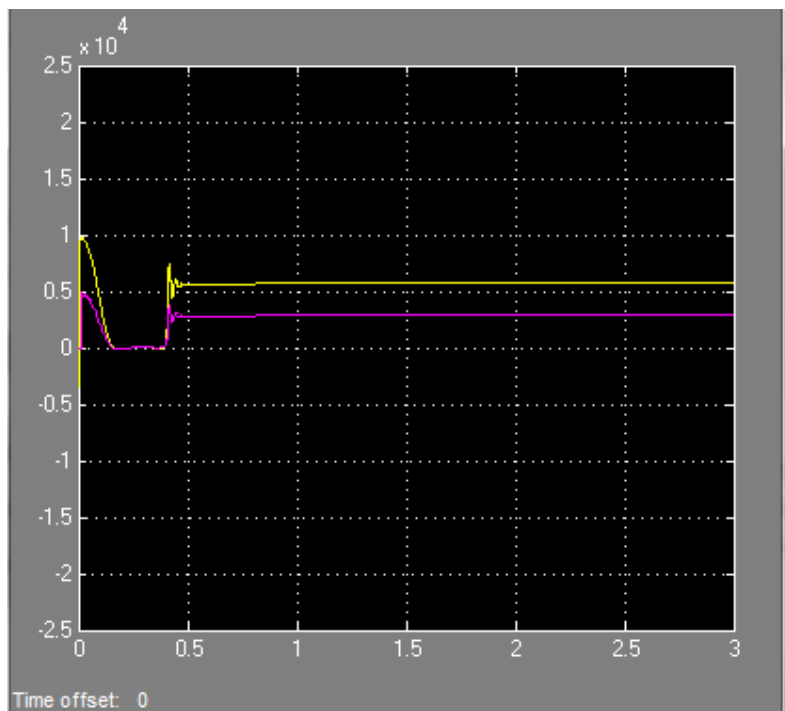


INCREMENTAL CONDUCTANCE

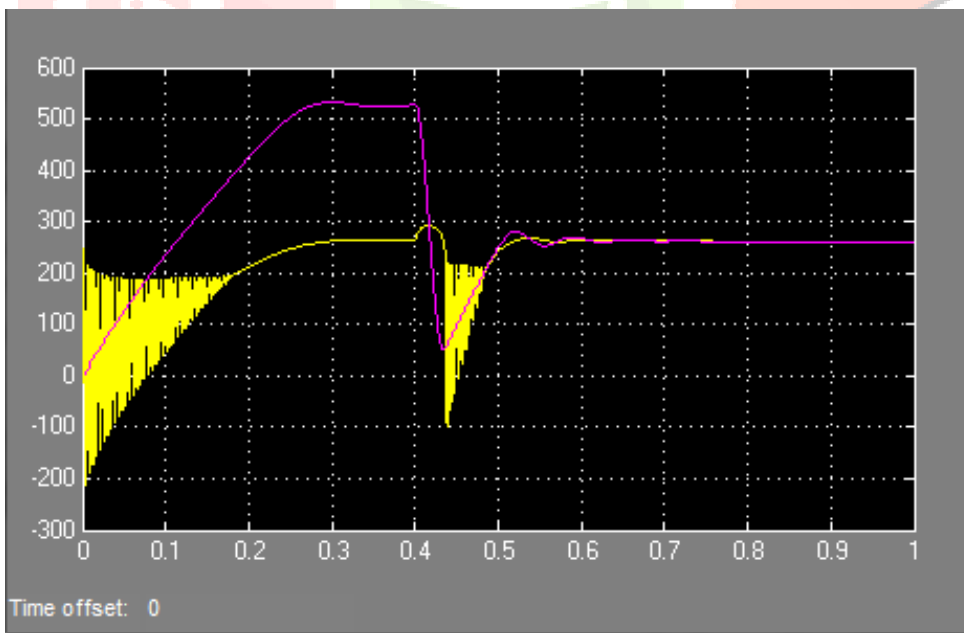
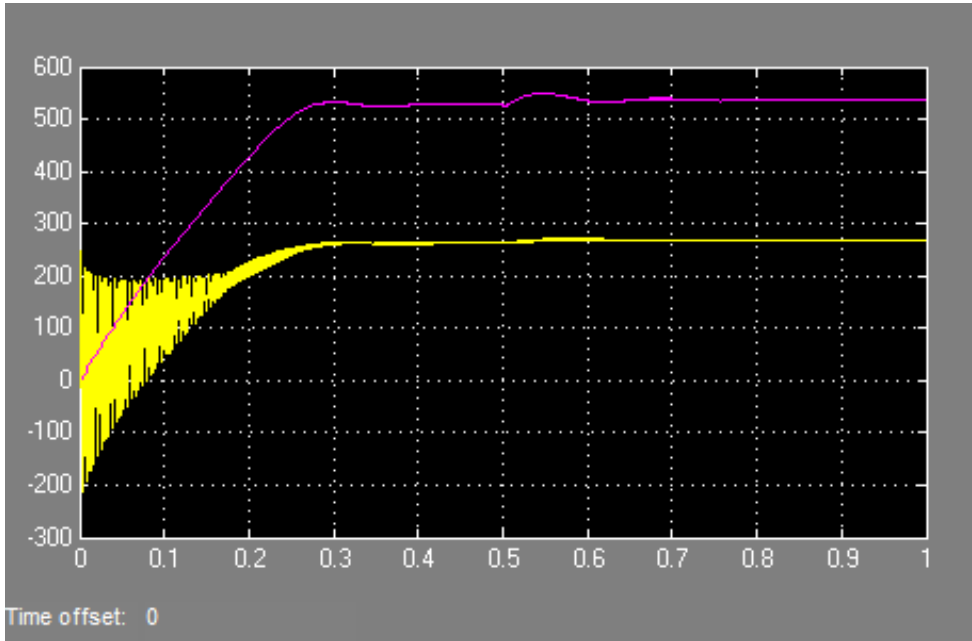


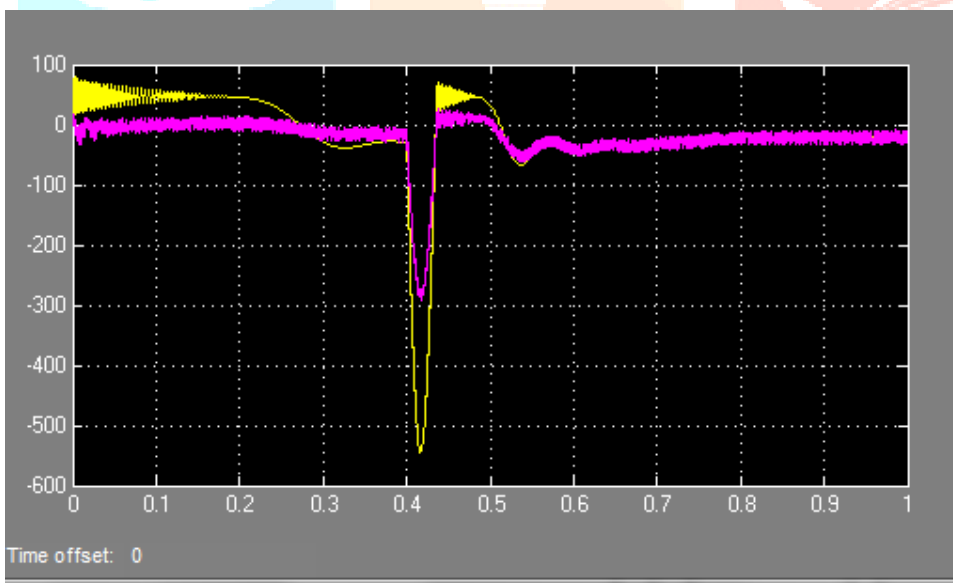
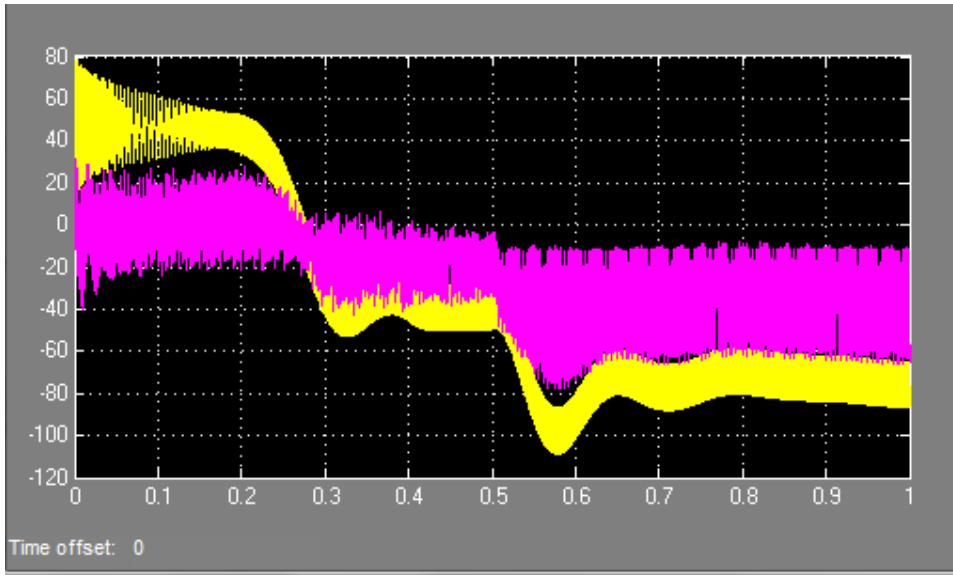


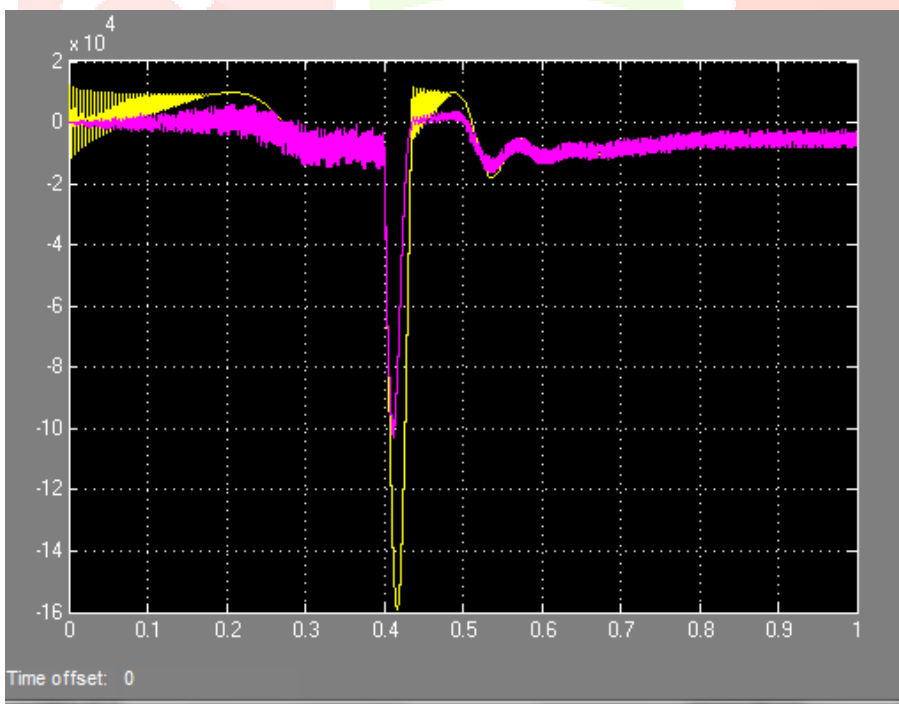
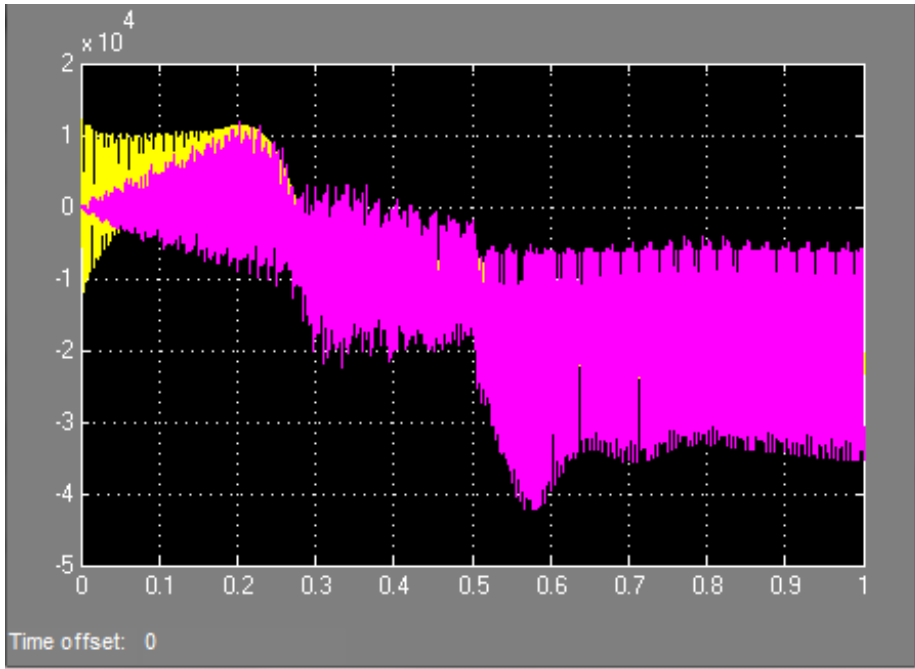




Fuzzy Logic Control







CON CLUSION The Model of a photovoltaic cell and photovoltaic array is built in the Matlab/Simulink software. Photovoltaic cell model is in single diode model and it is based by familiar Newton Raphson method. Voltage, Current and Power characteristics are simulated in Matlab/Simulink and it verified at different irradiance and temperature conditions. Maximum power point tracking is incorporated in the simulation of Photovoltaic array and the Maximum power point, voltage and current at this maximum power point were simulated at standard conditions and verified the result. The simulation system used for the analysis of solar photovoltaic array at different temperature value, solar irradiation value, series resistance R_s and shunt resistance R_{sh} . Behavior of the photovoltaic array in different diode ideality factor also analysed. This model can be used for analysis of Photovoltaic array characteristics and for simulation with different Maximum Power Point Tracking Algorithm (MPPT) algorithms.

The grid connected 10kW Photovoltaic systems simulated on Matlab/Simulink is shown in Fig.6.1. Fig.6.3. and Fig.6.5 (without MPPT) and comprise three graph in Fig.6.2, Fig.6.4 and Fig.6.6 of Voltage, Current and power with Maximum power point tracking (MPPT). The input to the simulation is given from the manufactures datasheets. The other simulation parameters are set as following values: $T_a = 25$ Degree Celsius, $A = 1.3$ (Polycrystalline solar cell). The simulation is carried standard condition to verify the working of Matlab/Simulink Photovoltaic model. The unknown parameters are calculated and voltage, current and power characteristics are simulated. The simulating system draws the voltage, current and Power of Maximum power point tracking graph are drawn and shown in Fig.6.2 and Fig.6.4 and Fig.6.6.

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