CHAPTER FOUR

MODELING AND SIMULATION OF GRID CONNECTED PHOTOVOLTAIC ARRAYS

4.1 Introduction

The complexity of the power grid, in conjunction with the ever increasing demand for electricity, creates the need for efficient analysis and control of the power system. The evolution of the legacy system towards the new smart grid intensifies this need due to the large number of sensors and actuators that must be monitored and controlled, the new types of distributed energy sources that need to be integrated of human-activity awareness into the smart grid is emerging and this will allow the system to monitor, share and manage information and actions on the business, as well the real world in this context, modeling and simulation is an invaluable tool for system behavior analysis, energy consumption estimation and future state prediction,a smart grid has been designed by MATLAP/ SIMULINK approach for analysis of active power.Analysis of active power gives the exact idea to know the range of maximum permissible loads that can be connected to their relevant bus bars. The change in the value of active power with varying load angle in context with small signal analysis. The smart grid regarded as the next generation power grid uses two way flow of electricity and information create a widely distributed automated energy delivery network can be represent in fig (4.1) [7].

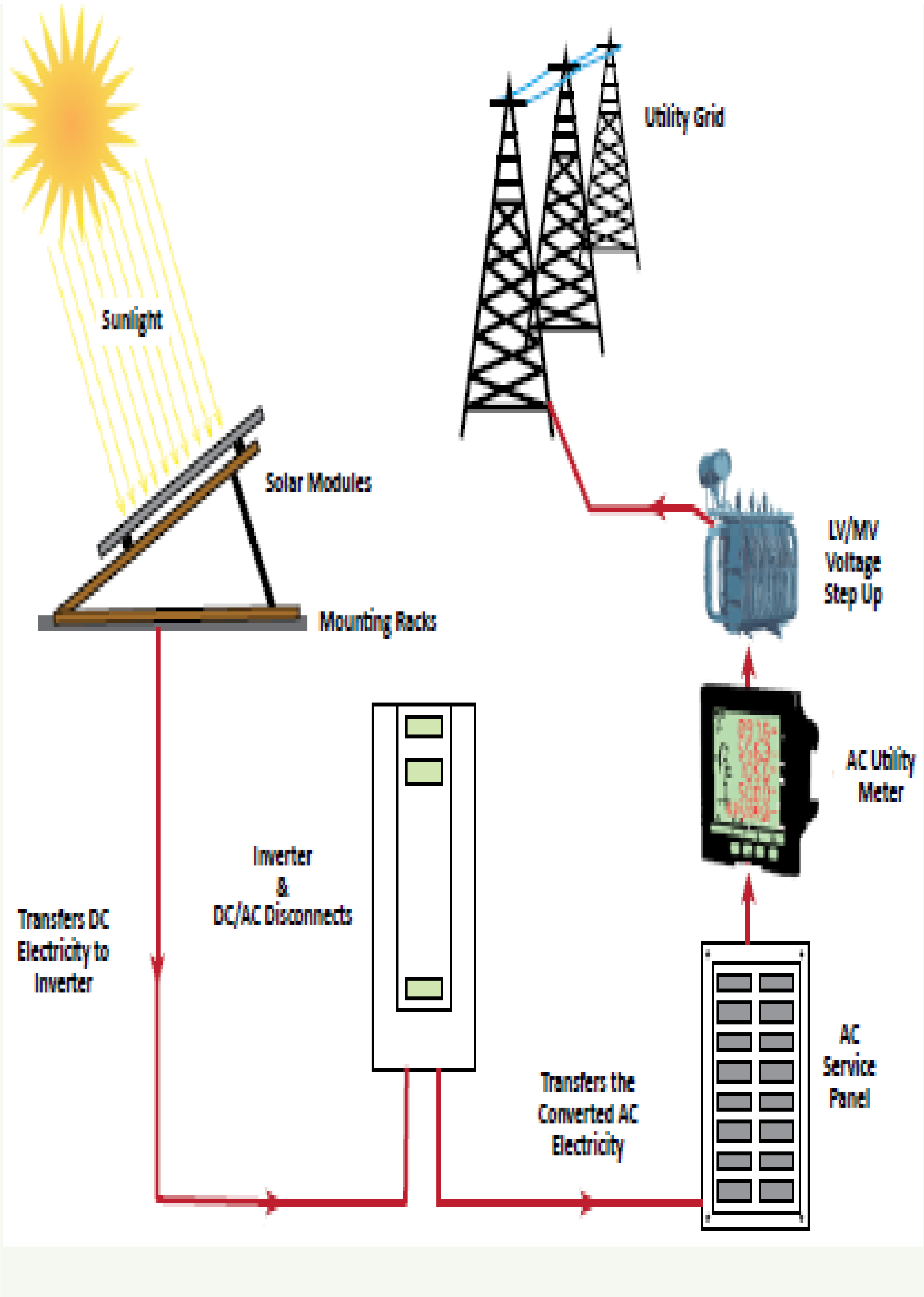


Fig (4.1) Smart grid system

4.2 System Main Block Diagram

The grid connected PV generator consist of three main components, PV array, voltage regulator and the inverter as shown in the following block diagram fig (4.2) and fig (4.3).

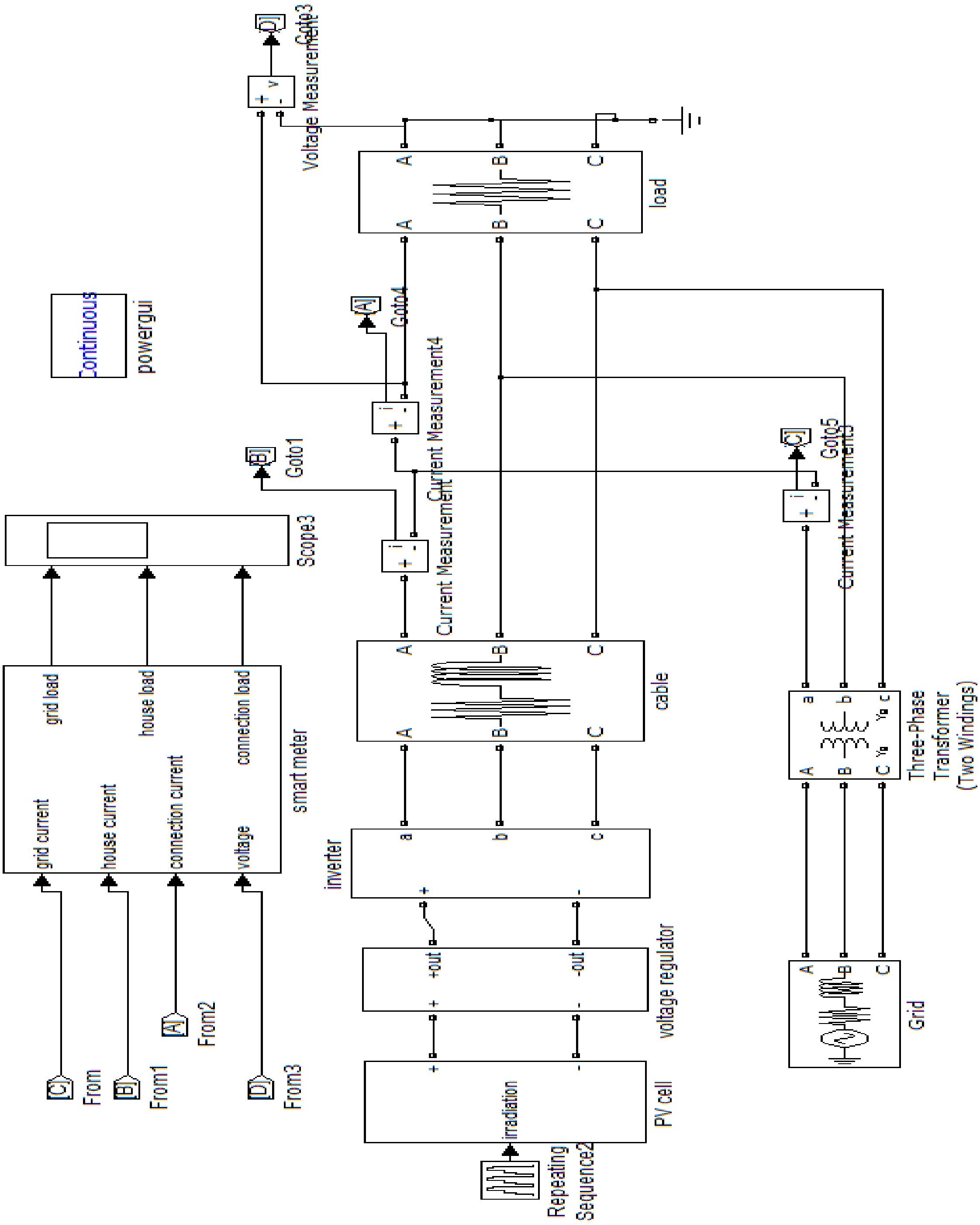


Fig (4.2) Overall PV grid connected system

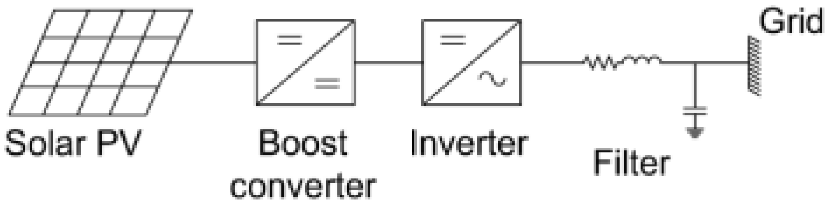


Fig (4.3) grid connected solar-PV generator.

4.2.1 Photovoltaic arrays

The general mathematical model for the solar cell has been studied over the past three decades. The circuit of the solar cell model, which consists of a photocurrent, diode, parallel resistor (leakage current) and a series resistor; is shown in Figure(4.4). According to both the PV cell circuit and Kirchhoff's circuit laws, the photovoltaic current can be presented as follows:

$$I_{pv} = I_{GC} - I_o\left[\exp^{\left(\frac{eV_d}{KFT_c}\right)} - 1\right] - \frac{V_d}{R_p} \qquad (4.1)$$

Where: Ipv =the photovoltaic current, IGC=the light generated current, Io =the dark saturation current dependent on the cell temperature, e=the electric charge e=1.6*10-19C, K=Boltzmann's constant, K=1.38*10-23 J/K, F=the cell idealizing factor, Tc=the cell's absolute temperature, Vd=the diode voltage, Rp=the parallel resistance.

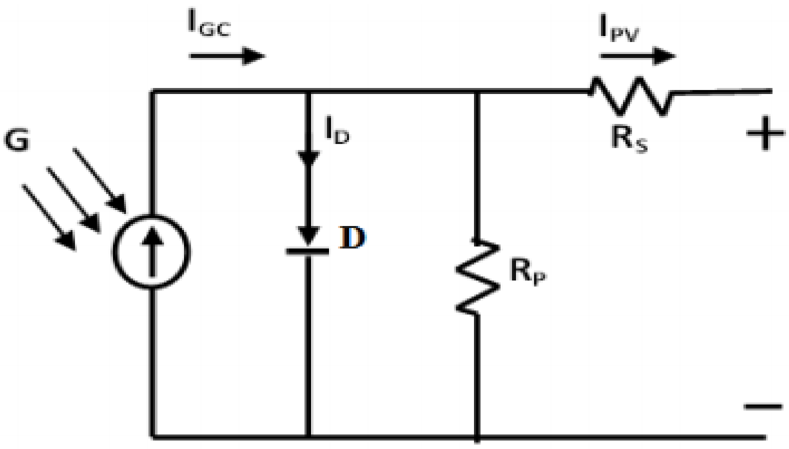


Fig (4.4) Single diode PV cell equivalent circuit

The photocurrent IGC mainly depends on the solar irradiation and cell temperature, 0which is described as:

$$I_{GC} = [\mu_{sc}(T_c - T_r) + I_{sc}]G \qquad (4.2)$$

Here: μsc=the temperature coefficient of the cell's short circuit current, Tr =the cell's reference temperature, ISC=the cell's short circuit current at a 25˚C and 1 KW/m2, G=the solar irradiation in KW/m2, Rs=the series resistance, D=the diode, ID=the current flowing in the diode.

Furthermore, the cell's saturation current (Io) varies with the cell temperature, which is described as:

$$I_o = I_{o\alpha}\left(\frac{T_c}{T_r}\right)^3 \exp^{\left[\frac{eV_g}{KF}\left(\frac{1}{T_r} - \frac{1}{T_c}\right)\right]} \qquad (4.3)$$

$$I_{o\alpha} = \frac{I_{sc}}{\exp^{\left(\frac{eV_{oc}}{KFT_c}\right)}} \qquad (4.4)$$

Where: Ioα =the cell's reverse saturation current at a solar radiation and reference temperature, Vg=the band-gap energy of the semiconductor used in the cell, Voc =the cells open circuit voltage.

-Current-voltage curve

At the fig (4.5) when the irradiation is increased to 1000w/m2 the current will increase to 15 Amp, etc. Conclusion from the above any increase in irradiation lead to increase in current.

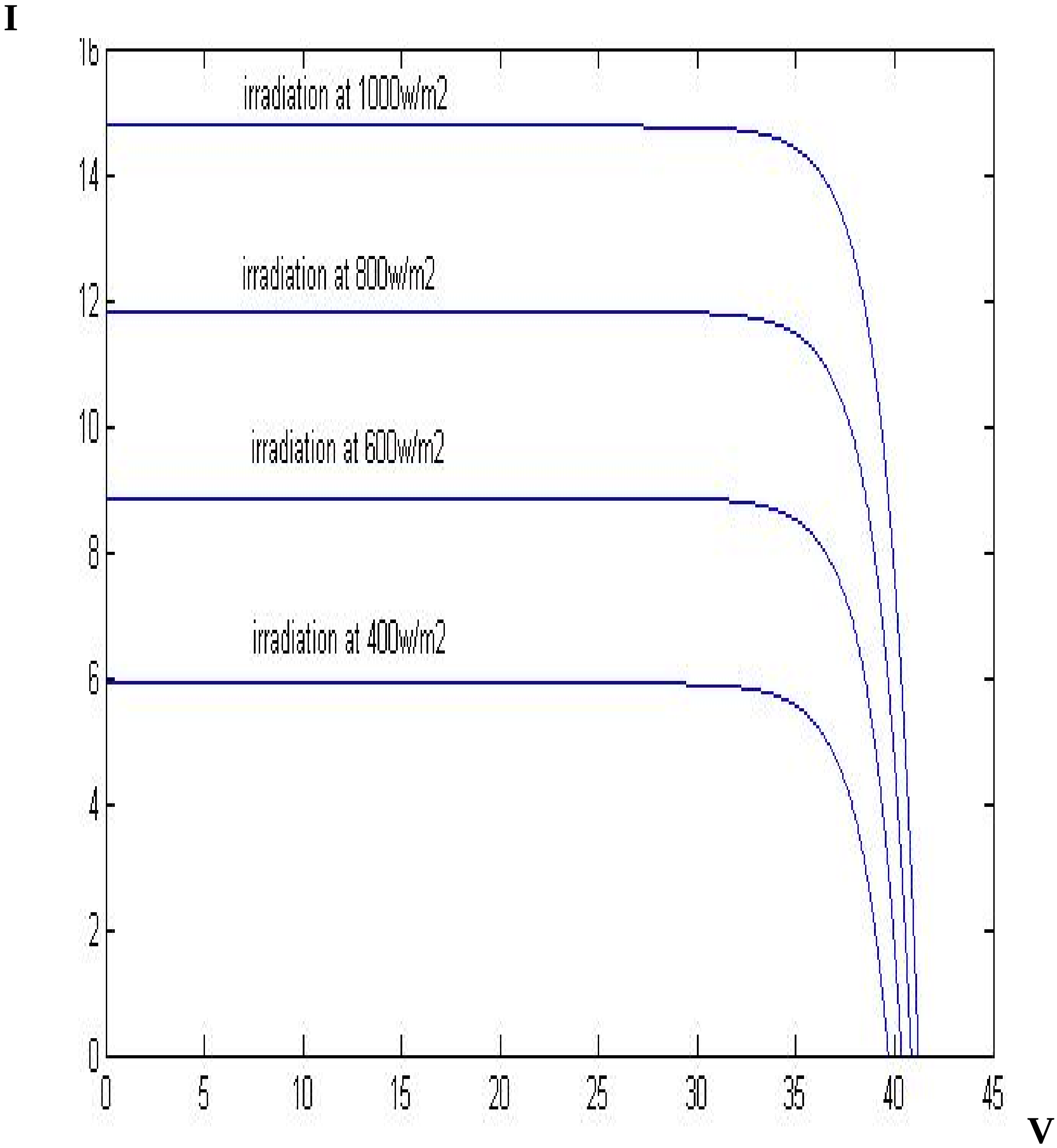


Fig (4.5) IV curve at different irradiation

-Power-voltage curve

At the Fig (4.6)when the irradiation is increased to 1000w/m the power will increased to 500w, etc. Conclusion from the above any increase in irradiation lead to increase in power.

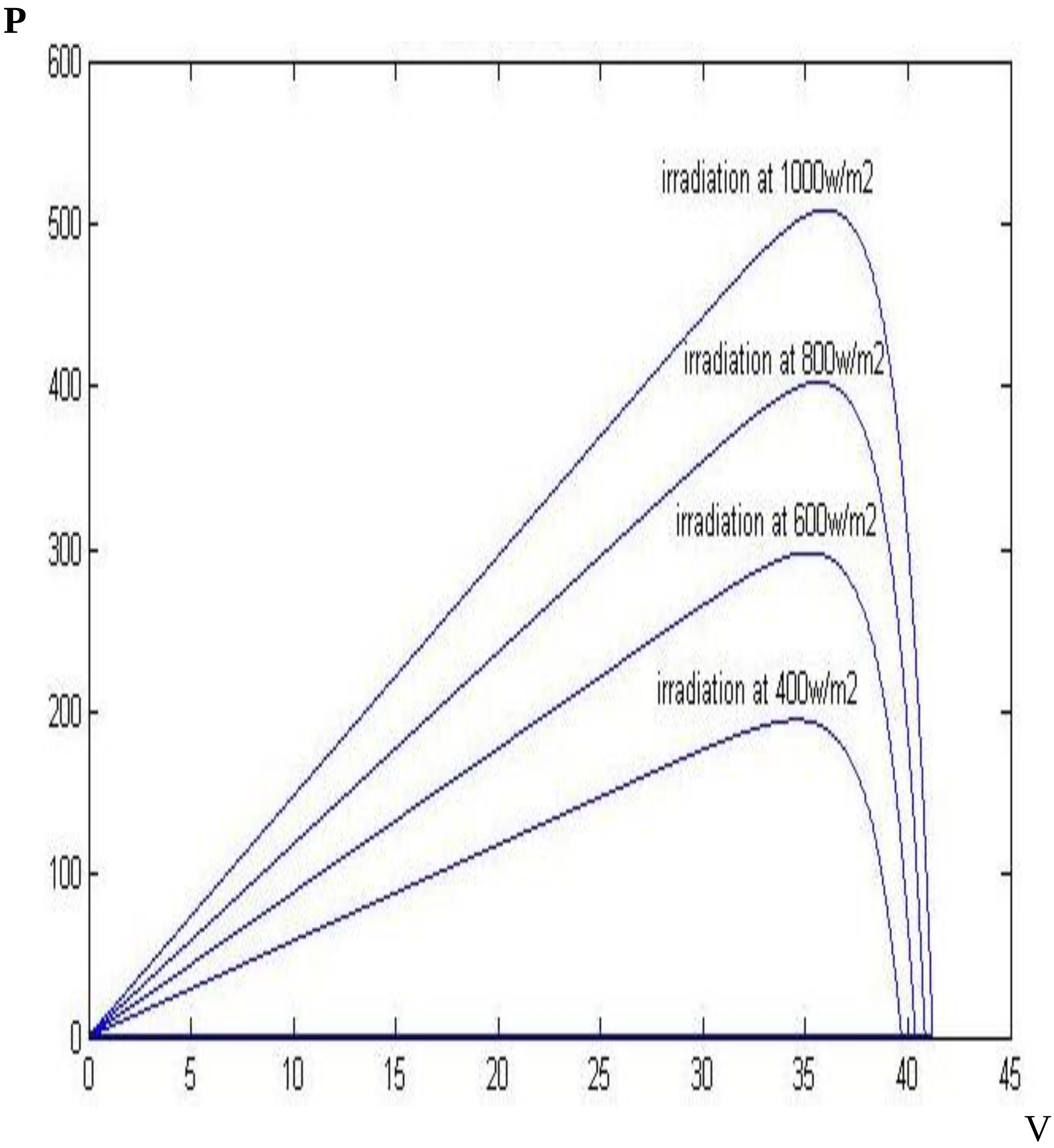


Fig (4.6) PV curve at different irradiation

4.2.2 Inverter

Inverter or power inverter is a device that converts the DC sources to ACsources. The input of the inverter is supplied from the voltage regulator which represent by battery to provide a voltage to produce maximum power from PV cell.

The inverter consist PWM controller, six IGPT/Diode for three phase and LC filter all of them show at figure (4.7).

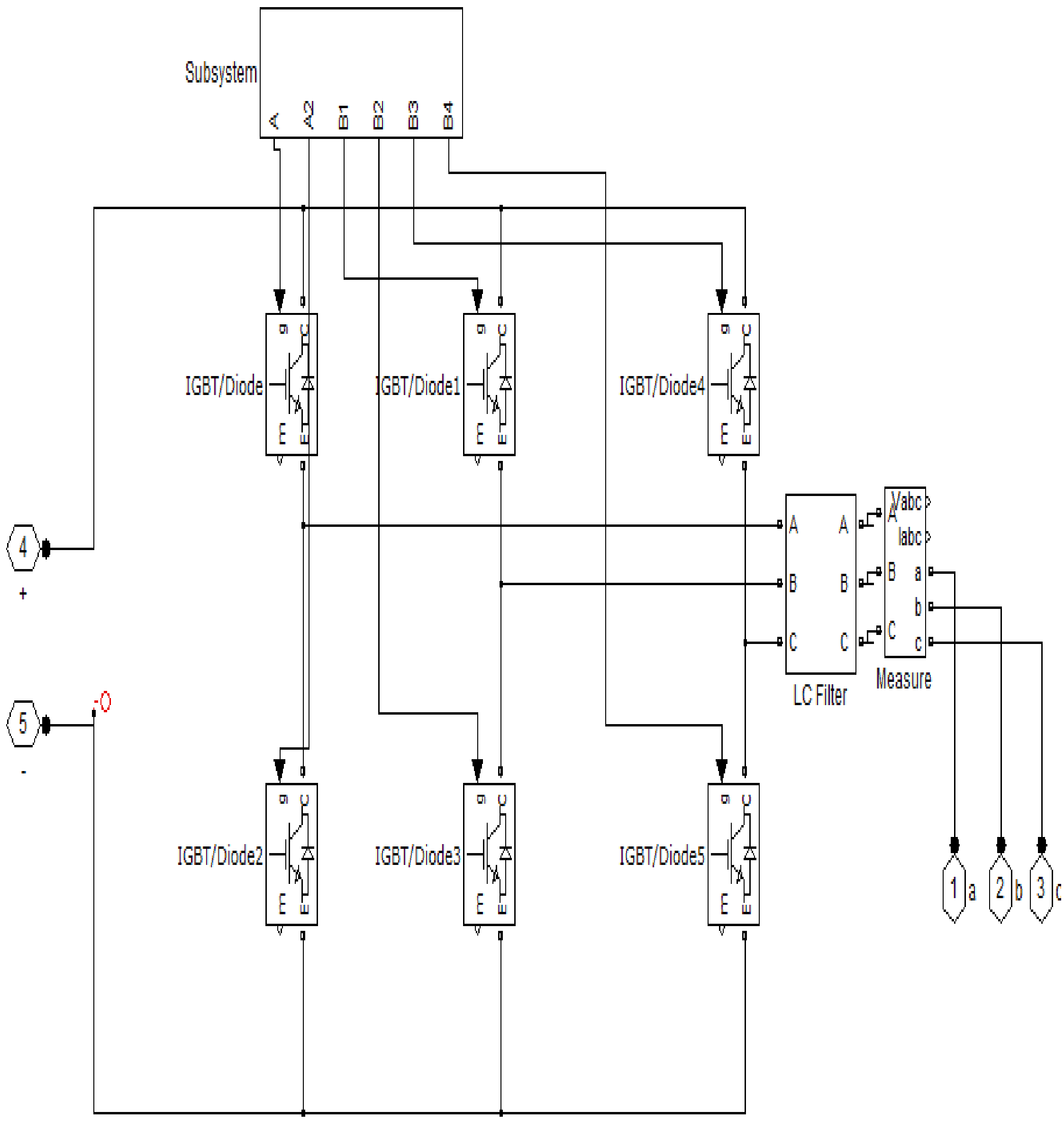


Fig (4.7) Inverter on matlab simulink

-Pulse width modulation

The inverter switching is controlled by the sinusoidal (PWM)gating signals which drive the gate of the IGBTs as shown in fig (4.8). In order to generate the gating signal (Vg) for the IGBTs by implementing the bipolar switching scheme, there are two inputs for the comparator which are a sinusoidal modulating signal (Vm) and a triangular carrier signal (Vcr). When Vm has higher magnitude than Vcr, the comparator output is high (ON), otherwise it is low (OFF). The gating signal generation which is illustrated in term of waveform is depicted in fig **(**4.9**)**.

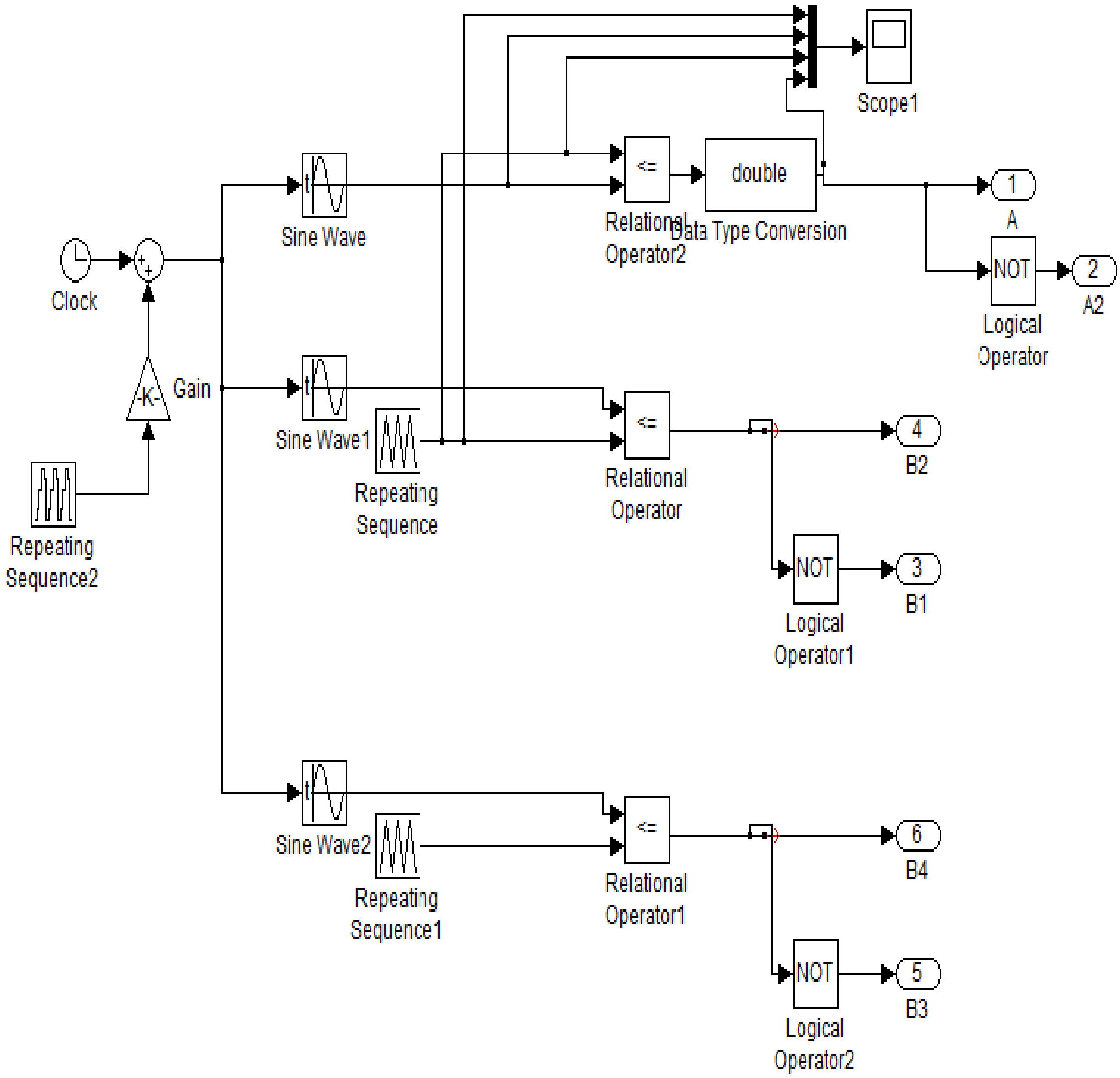


Fig (4.8) Inverter's' controller (PWM)

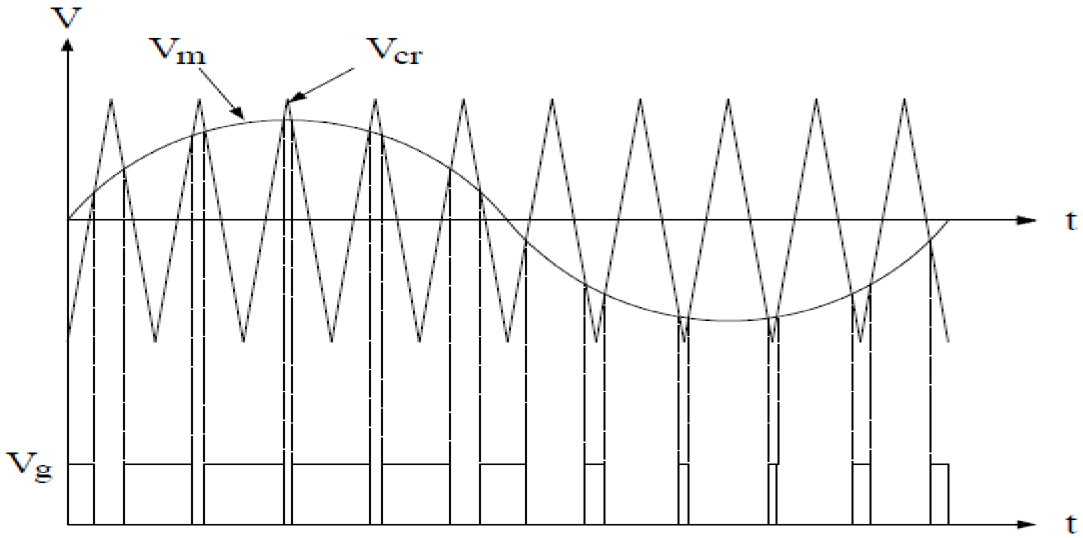


Fig (4.9) Producing PWM output voltage

-LC filter design

The (PWM) waveform of the inverter output voltage contains harmonics which the filter shown at fig (4.10) cleared this harmonics.

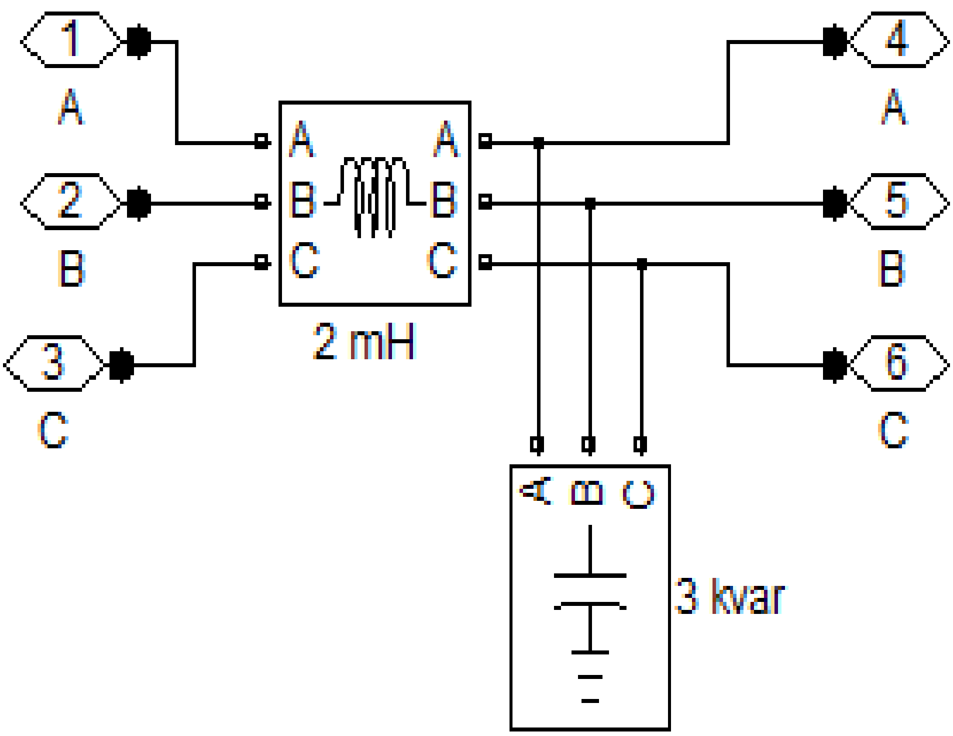


Fig (4.10) LC filter in matlab simulink

4.2.3 Smart meter

Smart meter explain where the system operation from electrical grid or PV cells, also calculate the power and tariff of it for consumer. This shown at the fig (4.11) bellow.

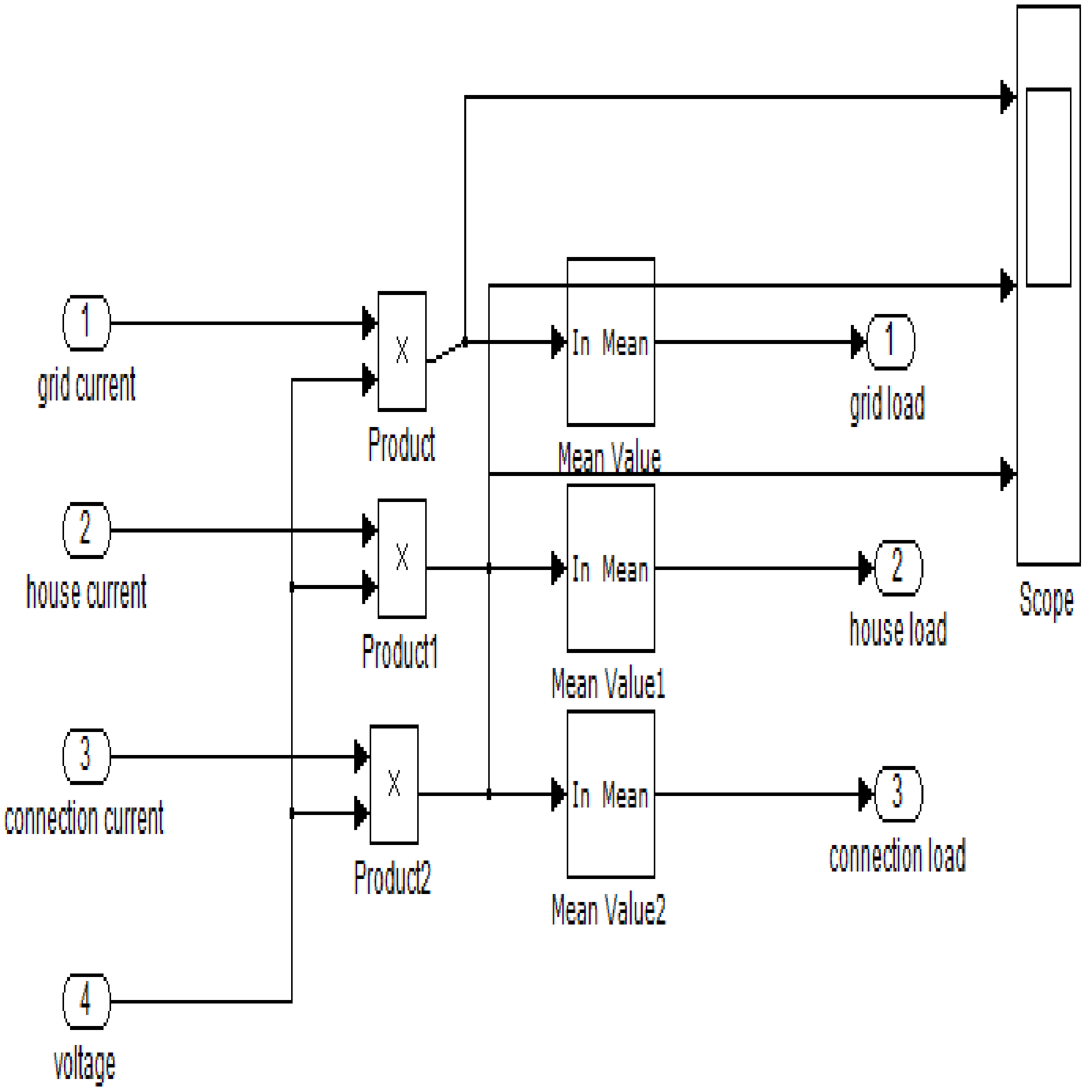


Fig (4.11) Smart meter on matlab simulink

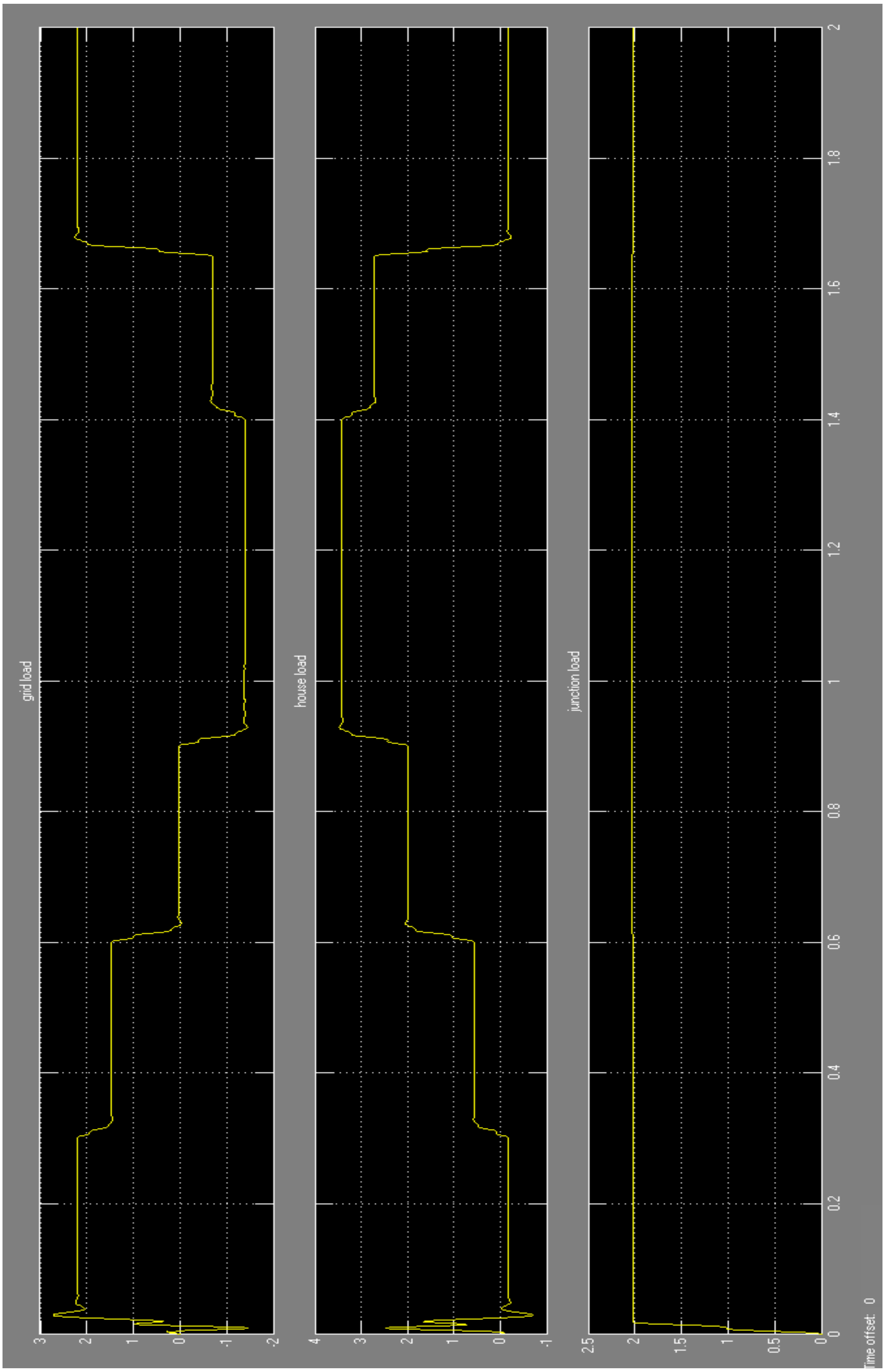
4.3 Simulink Code

```
el=1.6e-19
f=1.3
k=1.38e-23
tc=273
isc=3.69
voc=41.2
ns=54
np=4
µc=isc*.065
io=isc/(exp(el*voc/ns/k/f/tc))/np
```

4.4 Result

The figure (4.12) bellow explains the relationship between electrical grid load and house load with changing in time. During the day the load once supplied from electrical grid,once again from PV cells and other time from both of them.

Time



Power

Fig (4.12) power-time curve