Project Report

Stand alone and Grid connected Solar PV system And Control by Artificial Neural Network (ANN)

Ishan Budhiraja
2K18/EE/087

Gibson Muyembe
2K18/EE/069

Acknowledgment

We sincerely thank our teacher Prof. Uma Nangia, for her guidance and exhortation on this task and setting aside time for us from her busy schedule.

Abstract

Photovoltaic is the most common way for capturing the sun's energy. The sun's photons, or light, are used to generate electricity in photovoltaic PV. PV technology is based on the photoelectric phenomenon, which was initially reported in 1839 by a French physicist named Edmund Becquerel.

This DC can then be converted into alternating current AC, which is the primary form of electrical current in electrical power systems that are most commonly used in buildings. PV devices take advantage of the fact that the energy in sunlight will free electrical charge carriers in certain materials when sunlight strikes those materials .This flowing of electrons is an electrical current. This electron flow can be gathered in the form of direct current DC.

This DC can then be converted to alternating current AC, which is the predominant form of electrical current utilised in most building electrical power systems. PV devices take advantage of the fact that when sunlight strikes particular materials, it frees electrical charge carriers in those materials. The liberation of electrical charge allows light energy to be captured as electrical current.

In general, photovoltaic PV arrays convert sunlight into electricity. DC power generated depends on illumination of solar and environmental temperature which are variable. It is also varied according to the amount of load. Under uniform irradiance and temperature, a PV array exhibits a current-voltage characteristic with a unique point, called maximum power point, where the PV array produces maximum output power.

In order to provide the maximum power for load, the maximum-power-point-tracking MPPT algorithm is necessary for PV arrays. Briefly, an MPPT algorithm controls converters to continuously detect the instantaneous maximum power of the PV array

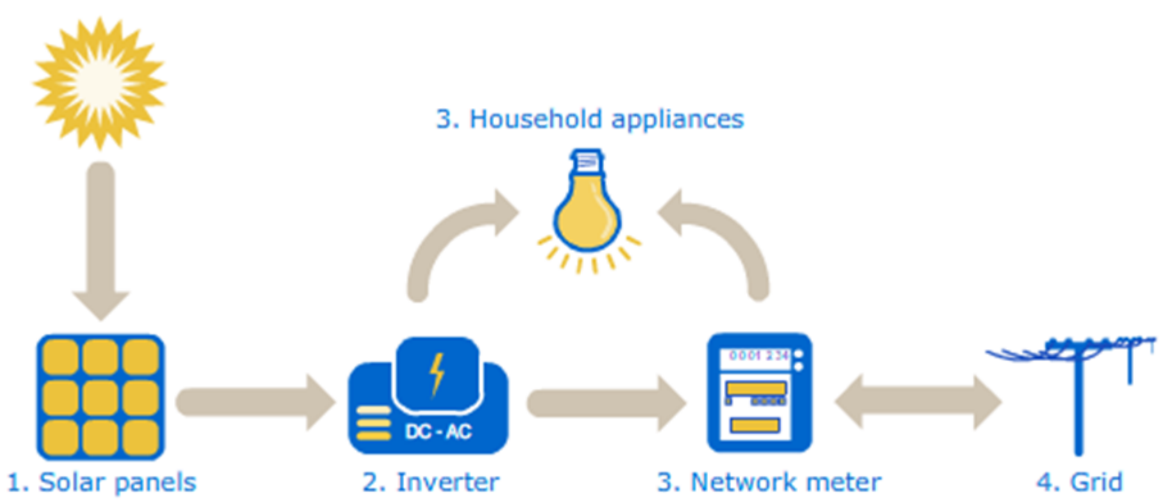
Contents

Photovoltaic System

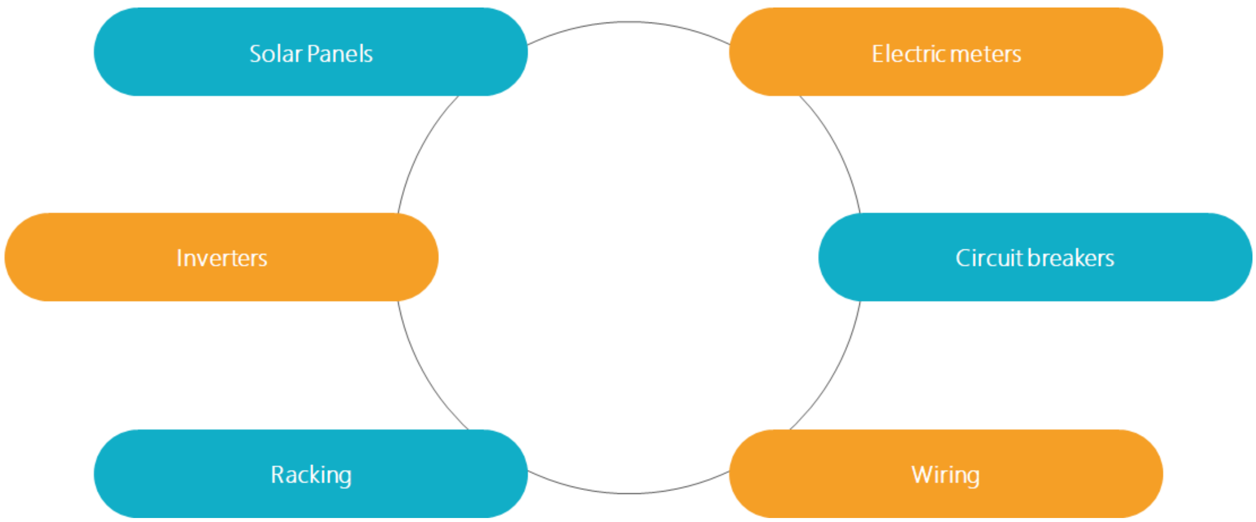
A photovoltaic (PV) system is made up of one or more solar panels, an inverter, and other electrical and mechanical components that use the Sun's radiation to generate power.
PV systems come in a wide range of sizes, from small rooftop or portable systems to large utility-scale power plants.

The photovoltaic effect occurs when light from the Sun, which is made up of packets of energy called photons, falls upon a solar panel and generates an electric current.
Each panel produces a little quantity of electricity on its own, but when linked together as a solar array, they may create larger amounts of energy.

Direct current is the type of power generated by a solar panel (or array) (DC). Although many electronic gadgets, such as your phone or laptop, use DC electricity, they are designed to work with the electrical utility system, which uses alternating current (AC)
As a result, solar electricity must first be converted from DC to AC using an inverter before it can be used. The inverter's AC electricity can either be used to power local gadgets or transferred to the electrical grid for use elsewhere.



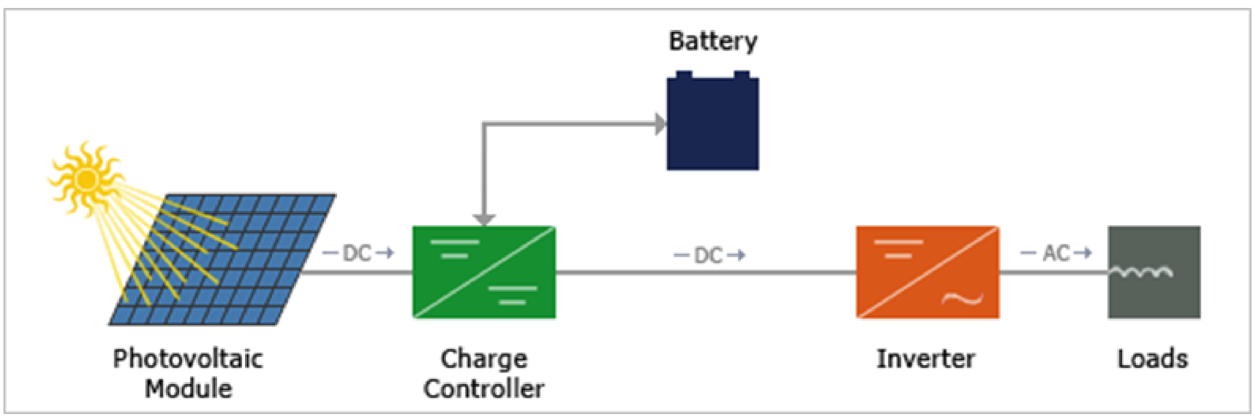
System Components of a PV system



Stand Alone PV system

Stand-alone systems are not connected with utility power lines and these are self sufficient systems. These systems could either be used to charge the batteries that serve as an energy storage device or could work directly using the solar energy available in the daytime. These systems consist of the following:

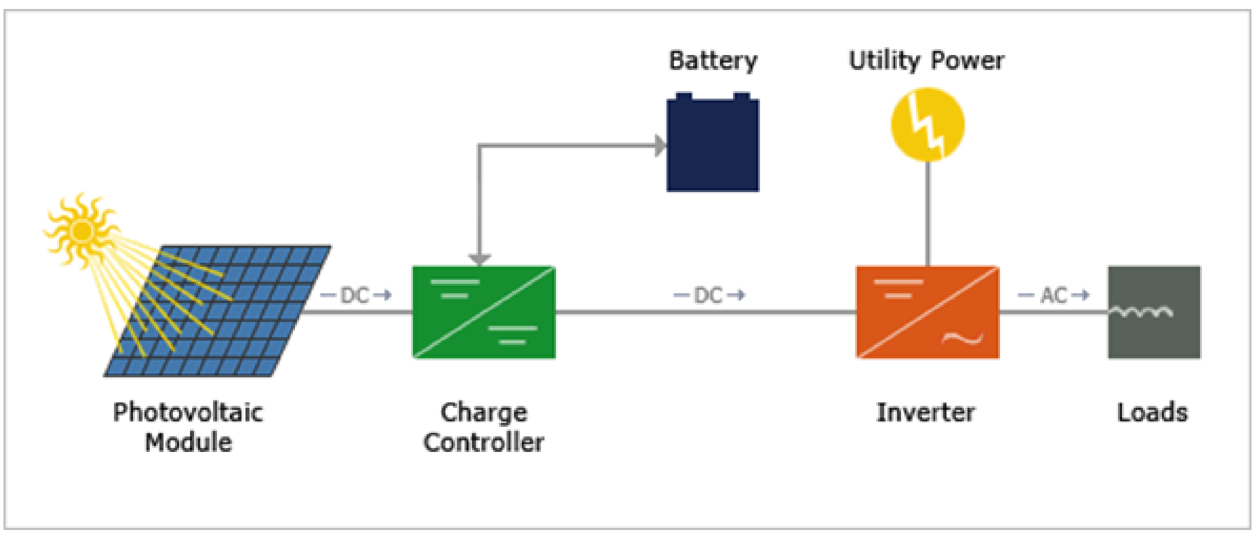
- Solar panels can be installed on the roof or in the open. Photovoltaic modules generate electrical power in the form of direct current (DC).
- Solar panels create DC energy, which is stored in batteries.
- Charge controller to prevent the battery from being overcharged.
- The system's electricity is converted from DC to AC using an inverter.



Grid Connected PV system

A grid connected photovoltaic system will be interacted with utility grid. The main advantage of this system is that power can be drawn from the utility grid and when power is not available from the grid, the PV system can supplement that power. These grid connected systems are designed with battery or without battery storage. These systems consist of the following:

- Solar panels can be installed on the roof or in the open. Photovoltaic modules generate electrical power in the form of direct current (DC).
- Solar panels create DC energy, which is stored in batteries.
- Charge controller to prevent the battery from being overcharged.
- Inverter specifically intended to convert PV-generated DC electricity to grid electricity (which is AC) at grid voltage.



Maximum Power point Tracking

Maximum power point tracking is used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions.

The efficiency of power transmission from the solar cell is dependent on the amount of sunlight falling on the solar panels, the temperature of the solar panels, and the electrical properties of the load, which is the core challenge addressed by MPPT.

The load characteristic that provides the best power transfer efficiency changes when these variables change. When the load characteristic changes, the system's efficiency is tuned to maintain the maximum possible power transfer efficiency. The maximum power point is the name given to this load feature (MPP).

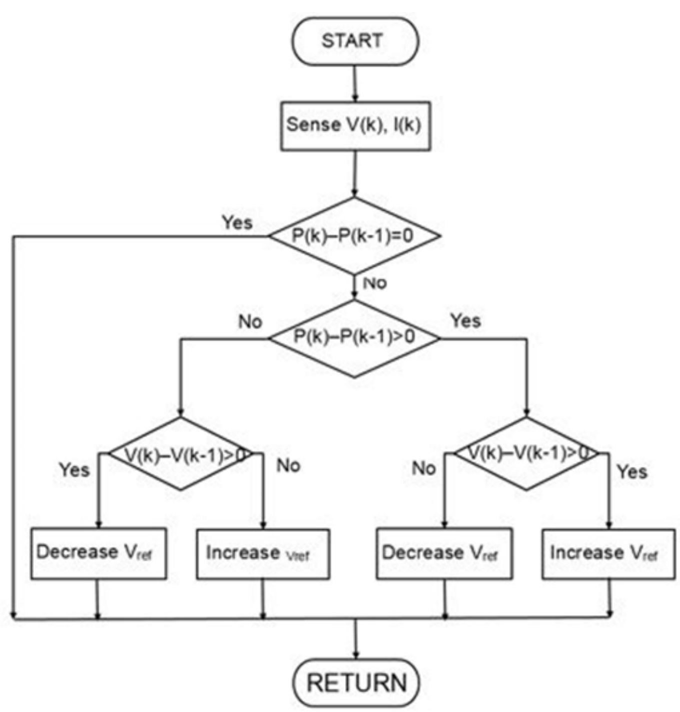
The technique of finding this point and maintaining the load characteristic there is known as MPPT. MPPT handles the problem of determining the optimal load to offer to the cells in order to get the most usable power out. Electrical circuits can be created to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems.

It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.

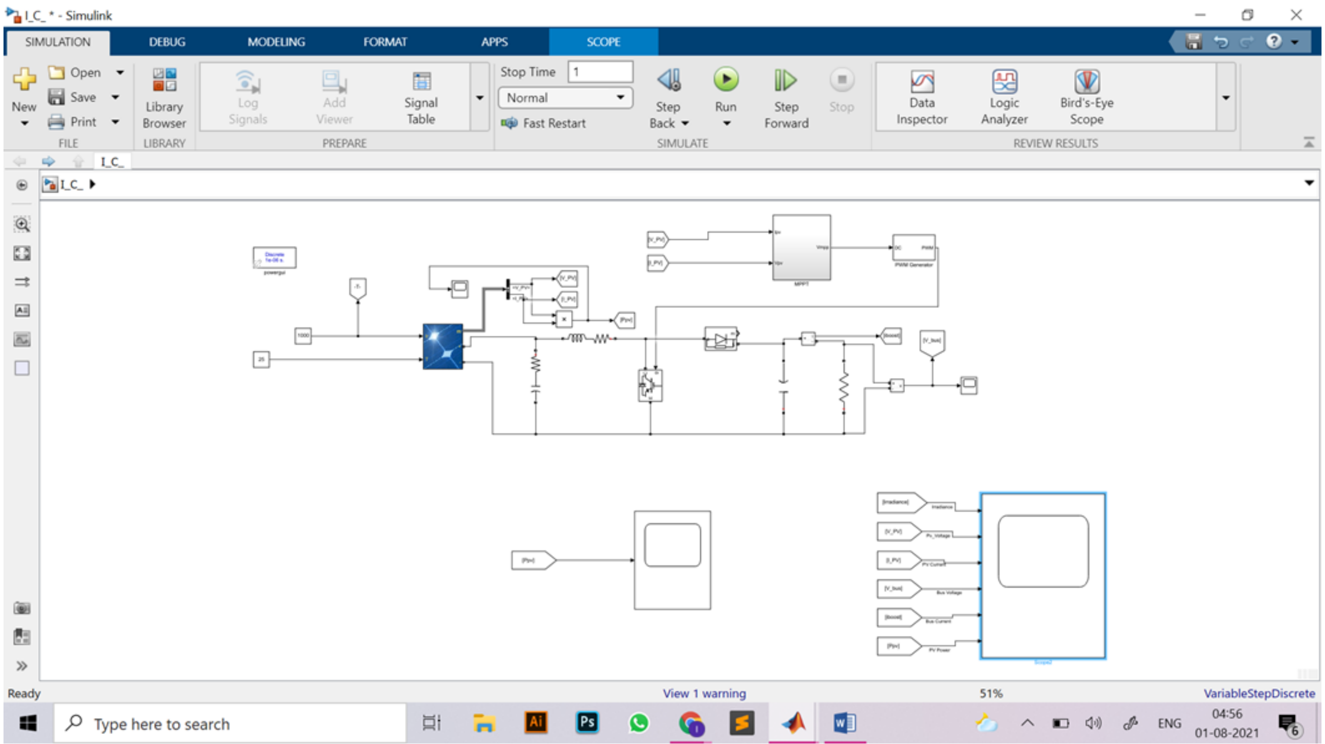
Perturbation and Observation (P&O)

The perturb and observe approach is easy to implement using analogue and digital circuitry and does not require prior knowledge of the PV generator parameters or the measurement of solar intensity and cell temperature. Even if the solar irradiance and cell temperature are constants, it disturbs the system's operating point, causing the PV array terminal voltage to oscillate around the MPP value.

Moreover, it is the most widely used and workhorse MPPT algorithm because of its balance between performance and simplicity. However, it suffers from the lack of speed and adaptability which is necessary for tracking the fast transients under varying environmental conditions. It is a simple and straightforward technique but degraded performance is achieved due to the trade-off between accuracy and speed upon selecting the step size.



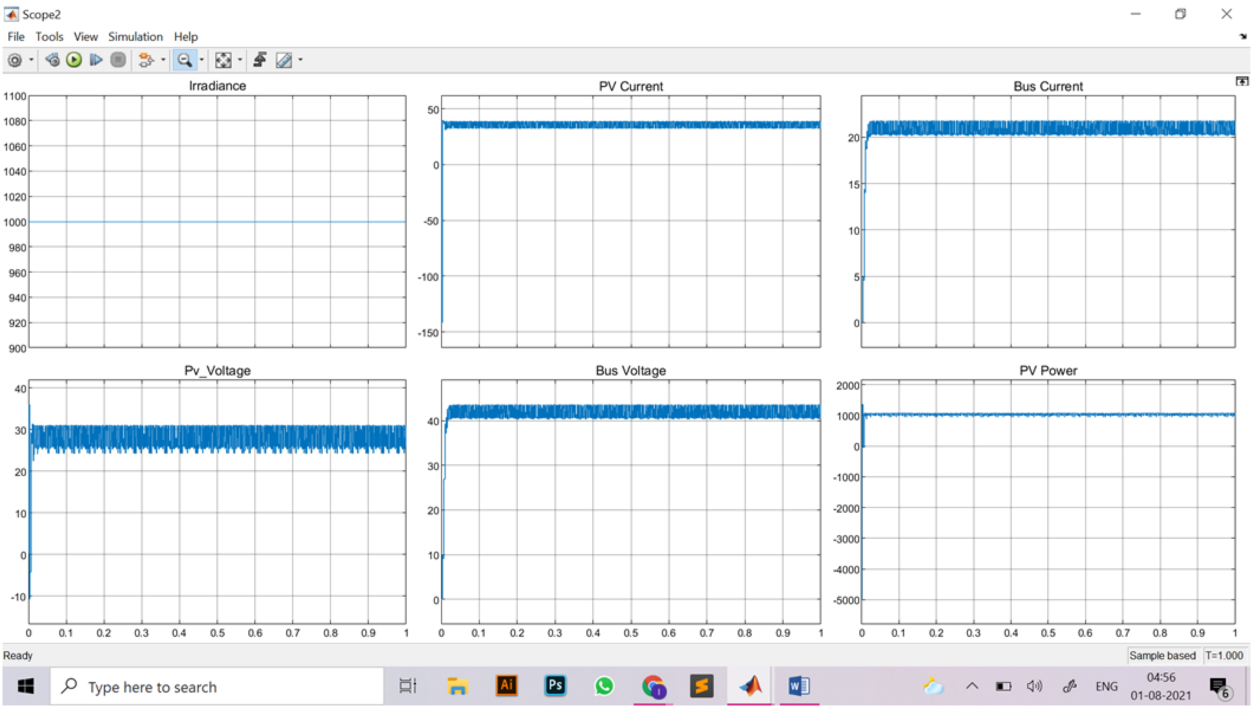
Matlab Implementation



Code Used

```
Function D  = PandO(V, I)

persistent Dprev Pprev Vprev

if isempty(Dprev)
    Dprev=0.7;
    Vprev=190;
    Pprev=2000;
end

deltaD = 125e-6;

Ppv=Vpv*Ipv;

if(Ppv-Pprev) ~= 0
    if (Ppv-Pprev)> 0
        if(Vpv-Vprev)>0
            D = Dprev - deltaD;
        else
            D = Dprev + deltaD;
        end
    else
        if (Vpv-Vprev) > 0
            D= Dprev + deltaD;
        else
            D = Dprev - deltaD;
        end
    end
else
    D=Dprev;
end

Dprev= D;
Vprev= Vpv;
Pprev= Ppv;
```

Results

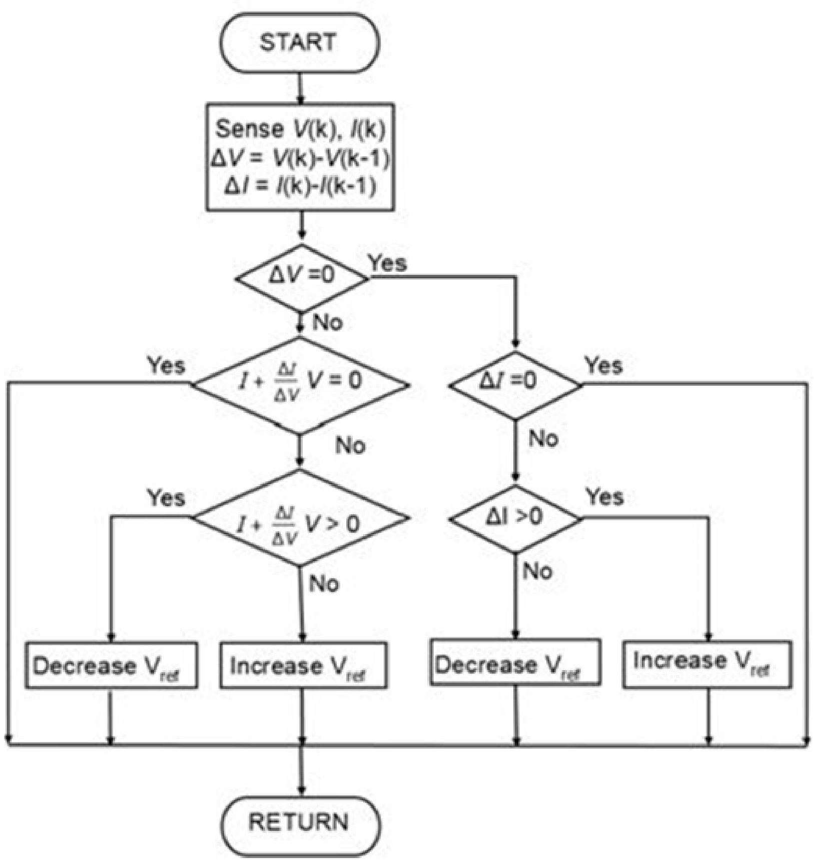

Scope2
File Tools View Simulation Help
Irradiance
PV Current
Bus Current
Pv_Voltage
Bus Voltage
PV Power
Ready
Sample based
T=1.000
Type here to search
ENG
04:56
01-08-2021

Incremental Conductance

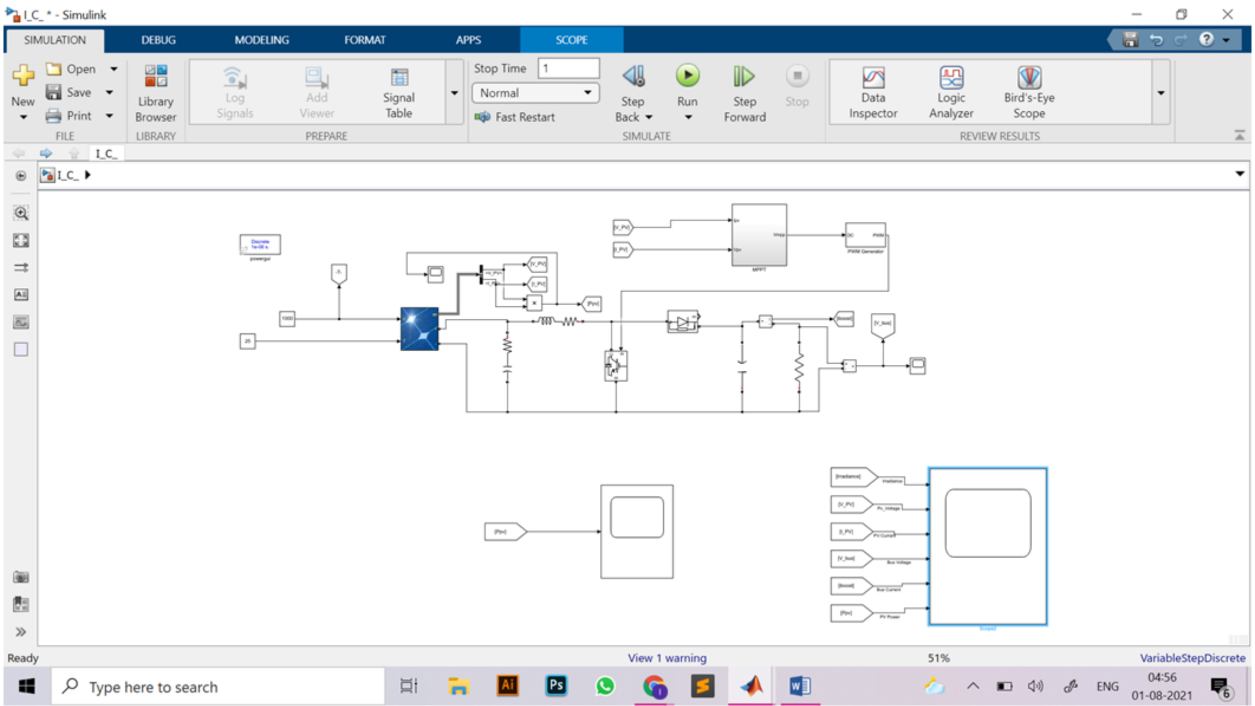
The incremental conductance method is based on the principle that the slope of the PV array power curve is zero at the MPP, so that $\Delta P/\Delta V = 0$, with $P = VI$.

Considering that

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \quad \text{if } P = \text{MPP},$$
$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \quad \text{if } P < \text{MPP},$$
$$\frac{\Delta I}{\Delta V} < -\frac{I}{V} \quad \text{if } P > \text{MPP},$$



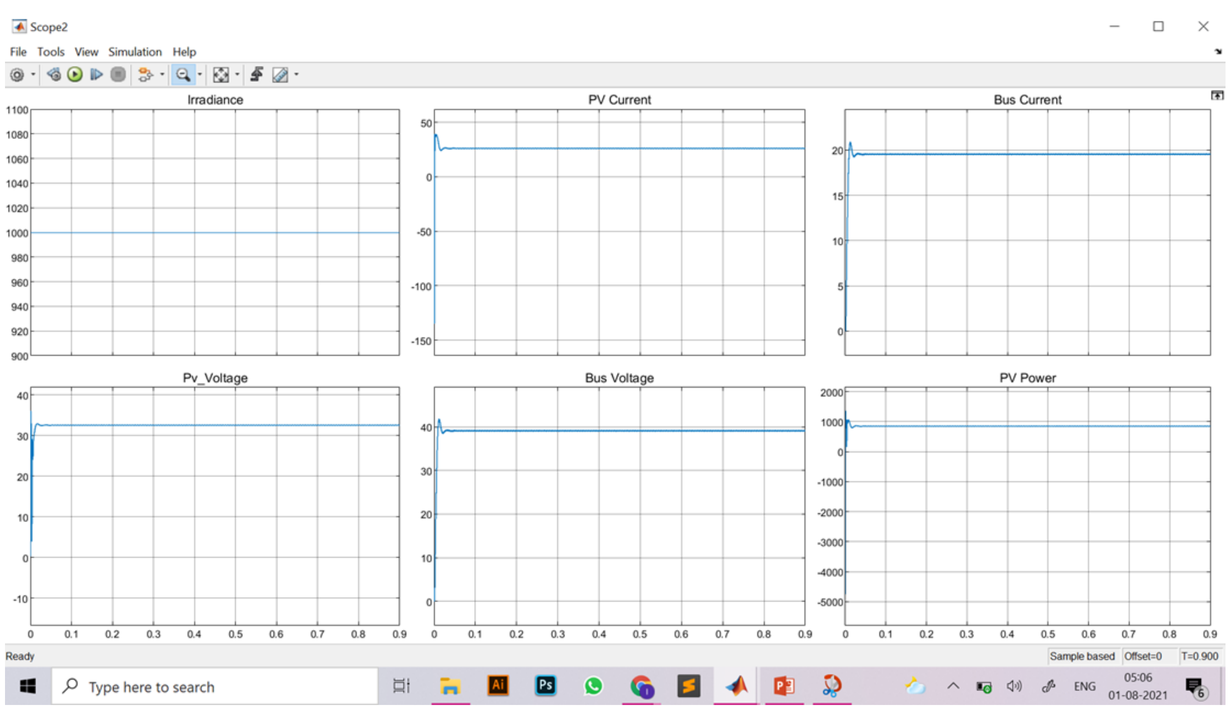
Matlab Implementation



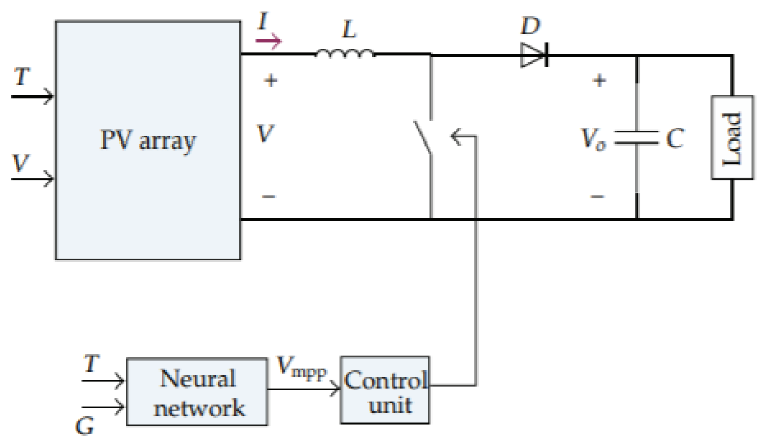
Code Used

```
function Vref = RefGen(V,I)

Vrefmax = 363;
Vrefmin = 0.0;
Vrefinit = 300;
deltaVref = 1;

persistent Vold Iold Vrefold;

dataType = 'double';

if isempty(Vold)
    Vold = 0;
    Iold = 0;
    Vrefold = Vrefinit;
end

dV = V - Vold;
dI = I - Iold;

if(dV == 0)
    if(dI == 0)
        Vref = Vrefold;
    else
        if(dI>0)
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    end
else
    if(dI/dV == (-I/V))
        Vref = Vrefold;
    else
        if(dI/dV > (-I/V))
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    end
end

if Vref >= Vrefmax || Vref <= Vrefmin
```

Results



PV Circuit

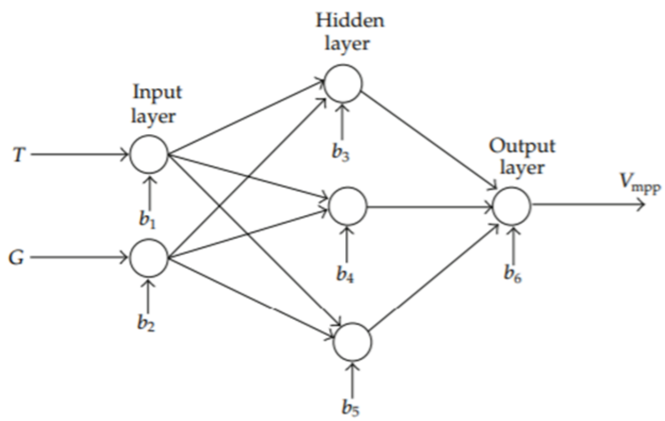


The Neural Network will Receive 2 inputs

Temperature

Irradiance

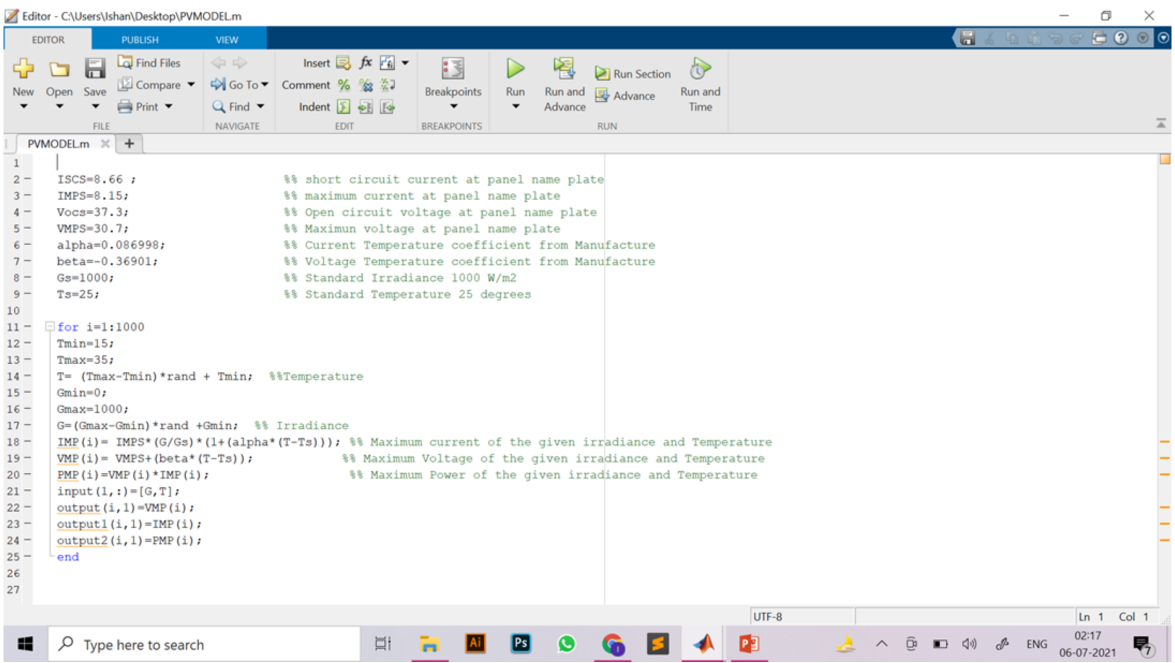
And based on this the network will provide maximum voltage for maximum power point

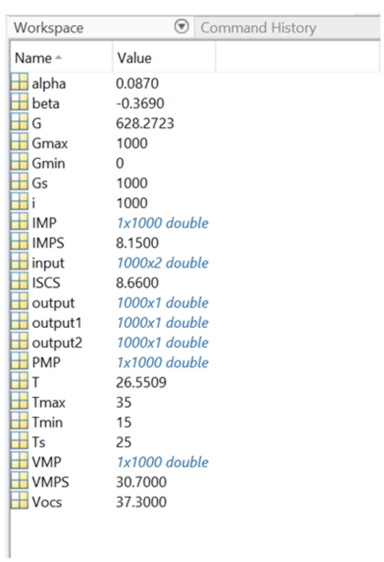


A three-layer neural network is used to reach MPP
Temperature T and irradiance G are two input variables and voltage of MPP Vmpp is the output variable of ANN.
It is necessary to obtain some data as input and output variable to train the neural network

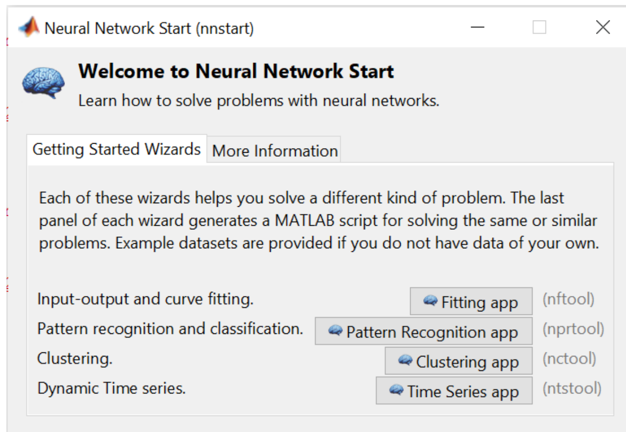
After training the ANN and specification of neuron weights, for any T and G as inputs of ANN, output of ANN is the Vmpp. Now, current of maximum power point Impp can be obtained by using V-I characteristic of the modeled PV. Consequently, maximum power Pmax is reached by multiplying Vmpp and Impp.

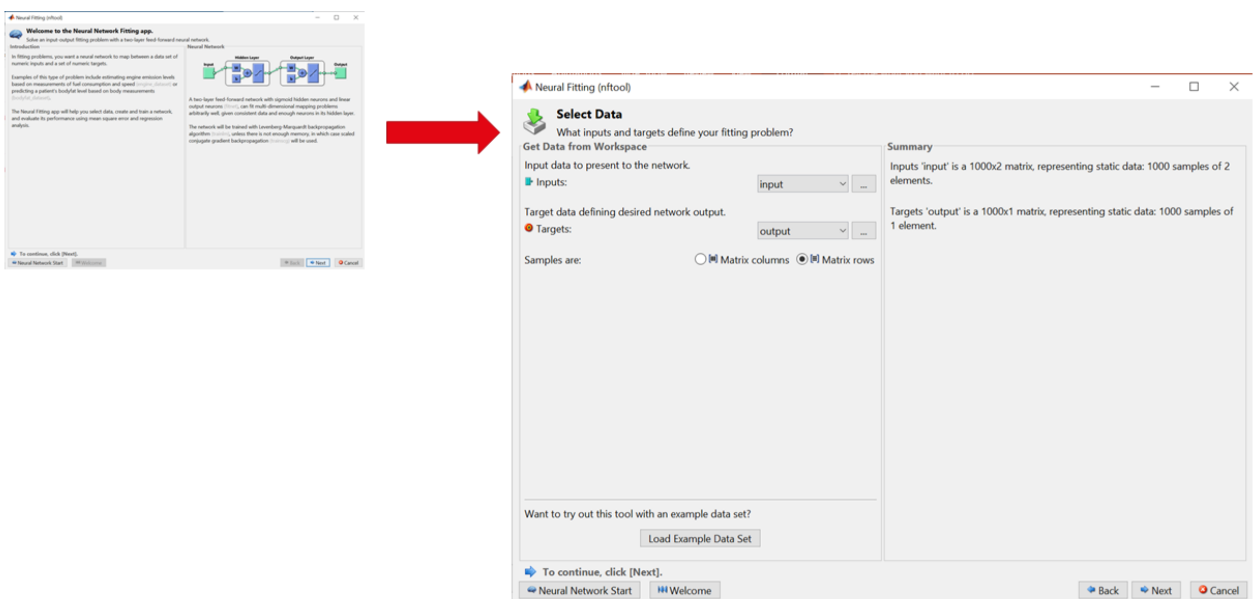
Collection of Data

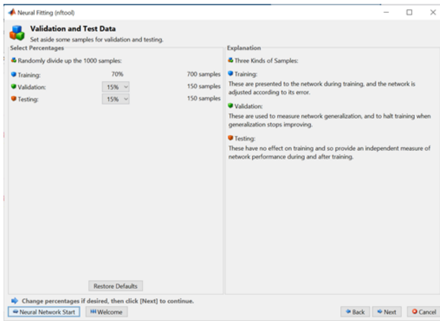


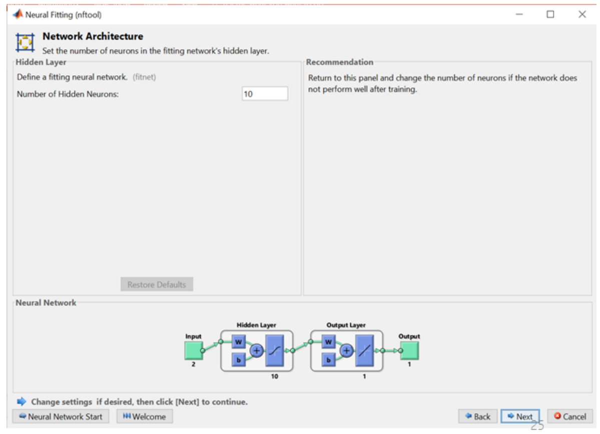


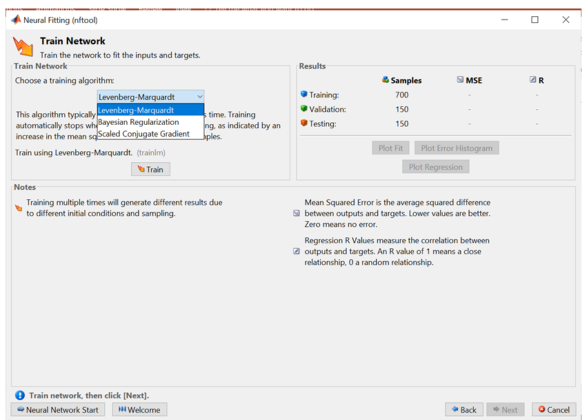
Training of Neural Network

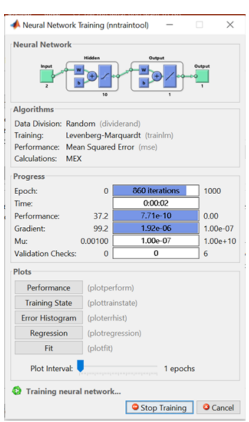


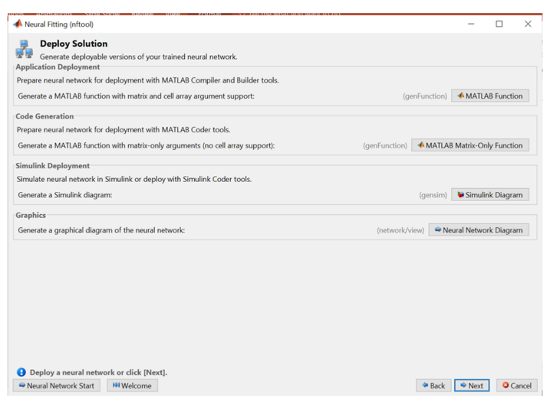


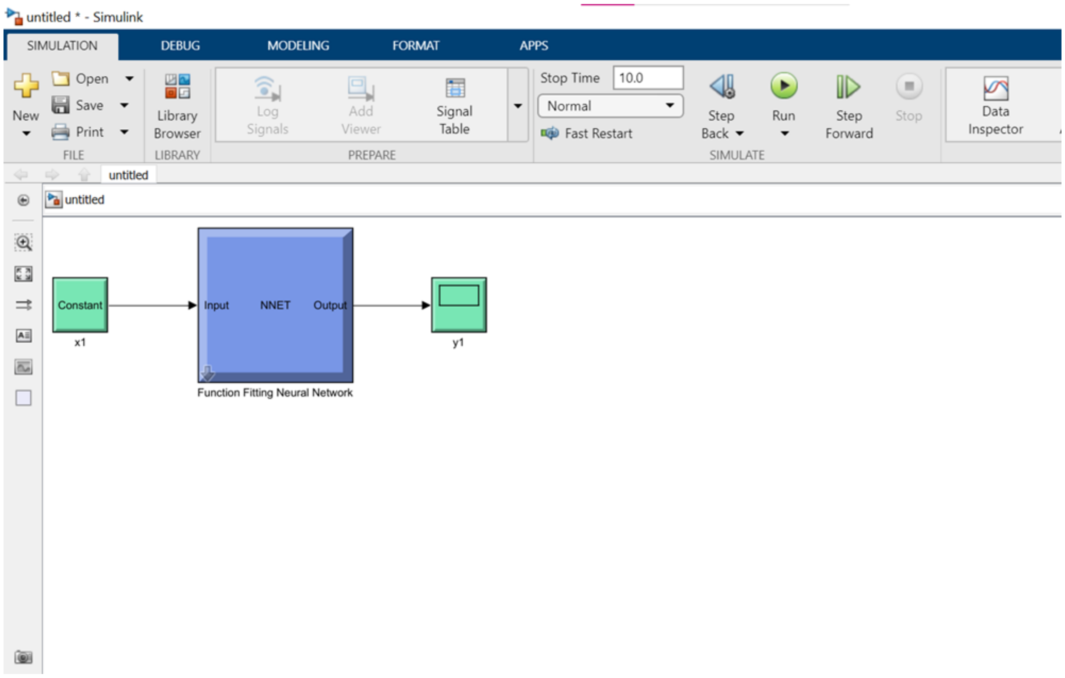

Neural Fitting (nftool)
Validation and Test Data
Set aside some samples for validation and testing.
Select Percentages
Randomly divide up the 1000 samples:
Training: 70% 700 samples
Validation: 15% 150 samples
Testing: 15% 150 samples
Explanation
Three Kinds of Samples:
Training:
These are presented to the network during training, and the network is adjusted according to its error.
Validation:
These are used to measure network generalization, and to halt training when generalization stops improving.
Testing:
These have no effect on training and so provide an independent measure of network performance during and after training.
Restore Defaults
Change percentages if desired, then click [Next] to continue.
Neural Network Start
Welcome
Back
Next
Cancel


Neural Fitting (nftool)
Network Architecture
Set the number of neurons in the fitting network's hidden layer.
Hidden Layer
Define a fitting neural network. (fitnet)
Number of Hidden Neurons: 10
Recommendation
Return to this panel and change the number of neurons if the network does not perform well after training.
Restore Defaults
Neural Network
Hidden Layer
Output Layer
Input
Output
Change settings if desired, then click [Next] to continue.
Neural Network Start
Welcome
Back
Next
Cancel

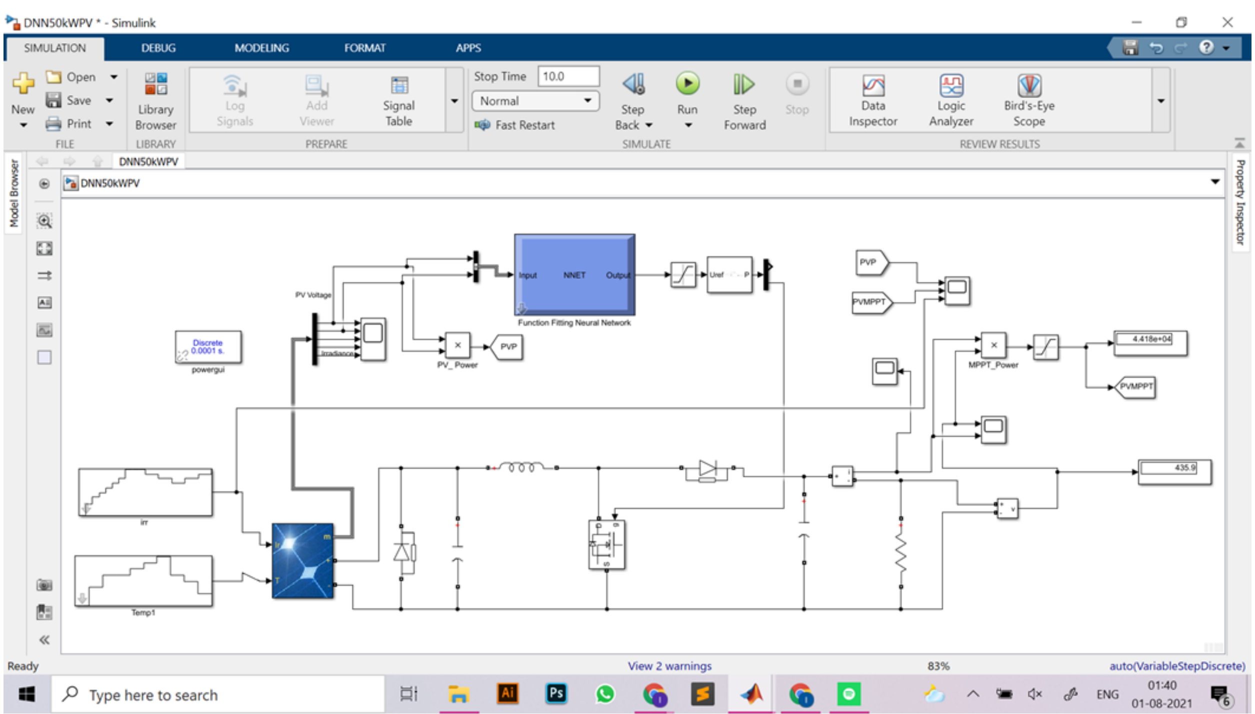

Neural Fitting (nftool)
Train Network
Train the network to fit the inputs and targets.
Train Network
Choose a training algorithm:
Levenberg-Marquardt
Levenberg-Marquardt
Bayesian Regularization
Scaled Conjugate Gradient
This algorithm typically … time. Training automatically stops wh… ng, as indicated by an increase in the mean sq… ples.
Train using Levenberg-Marquardt. (trainlm)
Train
Results
Samples
MSE
R
Training: 700
Validation: 150
Testing: 150
Plot Fit
Plot Error Histogram
Plot Regression
Notes
Training multiple times will generate different results due to different initial conditions and sampling.
Mean Squared Error is the average squared difference between outputs and targets. Lower values are better. Zero means no error.
Regression R Values measure the correlation between outputs and targets. An R value of 1 means a close relationship, 0 a random relationship.
Train network, then click [Next].
Neural Network Start
Welcome
Back
Next
Cancel


Neural Network Training (nntraintool)
Neural Network
Algorithms
Data Division: Random (dividerand)
Training: Levenberg-Marquardt (trainlm)
Performance: Mean Squared Error (mse)
Calculations: MEX
Progress
Epoch: 0 860 iterations 1000
Time: 0:00:02
Performance: 37.2 7.71e-10 0.00
Gradient: 99.2 1.92e-06 1.00e-07
Mu: 0.00100 1.00e-07 1.00e+10
Validation Checks: 0 0 6
Plots
Performance (plotperform)
Training State (plottrainstate)
Error Histogram (ploterrhist)
Regression (plotregression)
Fit (plotfit)
Plot Interval: 1 epochs
Training neural network...
Stop Training
Cancel

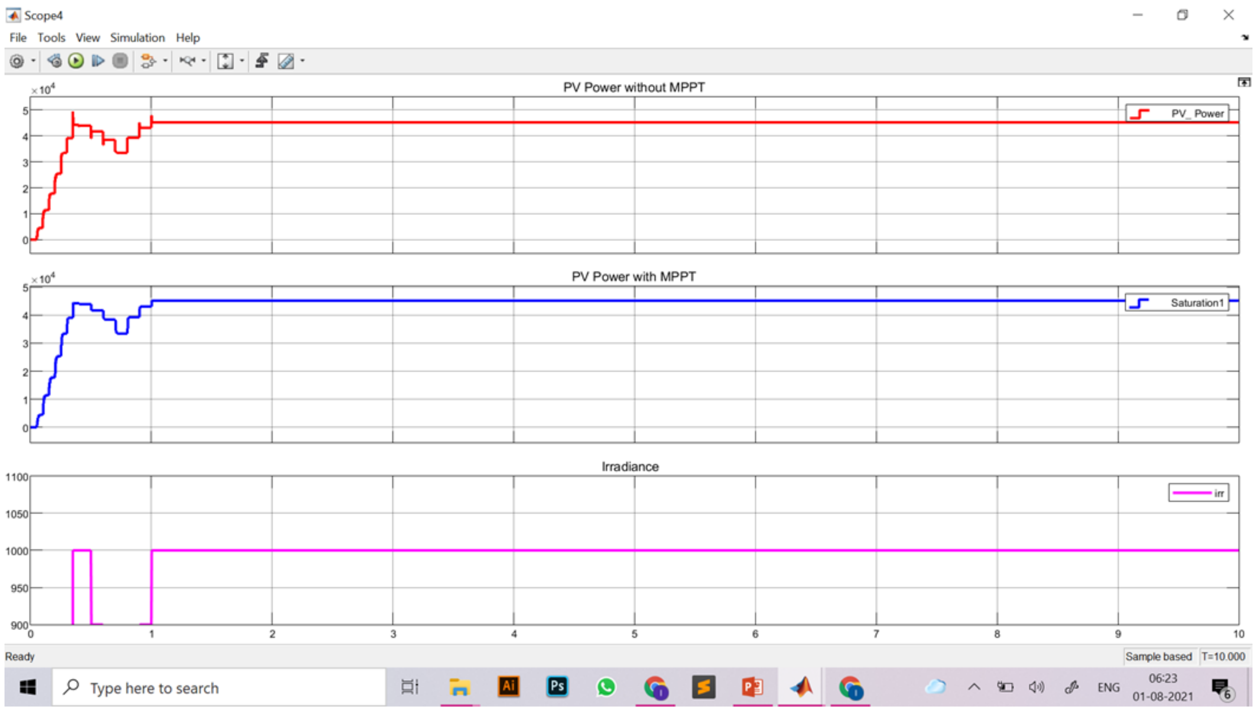

Neural Fitting (nftool)
Deploy Solution
Generate deployable versions of your trained neural network.
Application Deployment
Prepare neural network for deployment with MATLAB Compiler and Builder tools.
Generate a MATLAB function with matrix and cell array argument support: (genFunction) MATLAB Function
Code Generation
Prepare neural network for deployment with MATLAB Coder tools.
Generate a MATLAB function with matrix-only arguments (no cell array support): (genFunction) MATLAB Matrix-Only Function
Simulink Deployment
Simulate neural network in Simulink or deploy with Simulink Coder tools.
Generate a Simulink diagram: (gensim) Simulink Diagram
Graphics
Generate a graphical diagram of the neural network: (network/view) Neural Network Diagram
Deploy a neural network or click [Next].
Neural Network Start
Welcome
Back
Next
Cancel



MATLAB IMPLEMENTATION



RESULTS



- Under any variation in atmospheric conditions, by using a neural network, the point of maximum power is specified fast and precisely.

- Another advantage of the neural network in PV maximum power-point tracking is its better dynamic performance in comparison with the other methods.

- Also the maximum power point is tracked by dc-dc boost chopper. So the maximum power solar energy and the best efficiency are obtained.

References

1. https://energyeducation.ca/encyclopedia/Photovoltaic_system#:~:text=A%20photovoltaic%20(PV)%20system%20is,massive%20utility%2Dscale%20generation%20plants.

2. https://en.wikipedia.org/wiki/Photovoltaic_system

3. https://www.sciencedirect.com/topics/engineering/solar-photovoltaic-system

4. https://www.energy.gov/eere/solar/solar-photovoltaic-system-design-basics

5. https://www.investopedia.com/terms/a/artificial-neural-networks-ann.asp#:~:text=An%20artificial%20neural%20network%20(ANN)%20is%20the%20piece%20of%20a,by%20human%20or%20statistical%20standards.

6. https://www.solar-electric.com/learning-center/mppt-solar-charge-controllers.html/#:~:text=An%20MPPT%2C%20or%20maximum%20power,battery%20bank%20or%20utility%20grid.

7. https://www.hindawi.com/journals/ijp/2016/1728398/#:~:text=Different%20MPPT%20techniques%20have%20been,OCV
8. https://www.hindawi.com/journals/mpe/2012/506709/