IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)
ISSN(E): 2321-8843; ISSN(P): 2347-4599
Vol. 2, Issue 6, Jun 2014, 133-142

LOCATION BASE-MONTHWISE ESTIMATION OF PV MODULE POWER OUTPUT BY USING NEURAL NETWORK WHICH OPERATES ON SPATIO-TEMPORAL GIS DATA

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ABSTRACT

This research work focuses on evaluating location specific performance of PV panels for solar energy conversion to electrical energy. The proposed system facilitates plant designer to identify suitable location to improve efficiency of plant to meet energy demands increasing day by day.

The paper illustrate the web based software system that constituted by components such as Neural Network and Google Map Interface. The system use climatic data for specific region, supplied by satellite for training of NN. Then this system evaluates seasonal performance of the PV module at any location within the specific region for which system is trained.

KEYWORDS: Neural Network, Photovoltaic (PV), Nominal Operating Cell Temperature (NOCT), I-V Curve

INTRODUCTION

Photovoltaic (PV) cells based electrical power generation is widely applicable for power generation ranging from national grid to small domestic household uses. Solar Irradiance and Temperature affects overall performance of the PV module output to great extent. These both factors are location and time specific, thus it is important to have system which can evaluate overall annual performance of the module with respect to seasonal changes at respective location. This can help the Solar Power Plant designers to select appropriate PV modules, to identify suitable location for rated power and evaluate the plant performance against region specific climatic variation.

In India, annual solar radiation falling on 1 m^2 area in a year is about 1600 to 2200 kWh. For entire region of India that translates to about 6000 million GWh [1]. Thus it is a great potential to tap. Hence Government is promoting solar mission to enhance solar power generation in country. Ministry of New and Renewable Energy (MNRE) is very active towards solar power projects.

In January 2010, the Indian Government launched Jawaharlal Nehru National Solar Mission (JNNSM), with an overall aim to develop and promote solar energy applications in the country, with an aim of reaching grid parity for solar power by 2022. For this, a target of 20,000 megawatt (MW) of grid connected solar power has been envisage, which is in addition to an off grid target of 2,000 MW equivalent and cumulative growth of solar thermal collector area to 20 million square meter (m^2) by 2022[2]. The country is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude.

Hence the central idea of the paper is to develop a system tuned to specific region which will be useful for performance evaluation of PV panels over entire climatic variations within the region.

SOLAR PHOTOVALTAIC MODULES

Solar Photovoltaic (PV) modules are transducer which transforms solar radiation into electrical power. It can be considered as a big solar cell acting as DC source which provides electrical current when exposed to solar radiations. [4]

The solar PV module is obtained by interconnecting smaller solar cells in series and parallel combination in order to deliver desired electrical power.

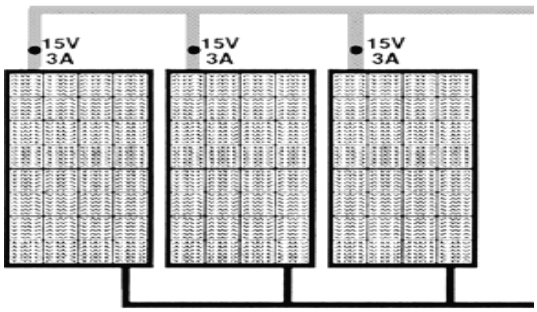

Figure 1: PV Modules

Photovoltaic Cells

At the present time, most commercial photovoltaic cells are manufactured using extremely pure silicon. Other, more exotic materials such as gallium arsenide also being used.

Photovoltaic Modules

For almost all applications, the one-half volt produced by a single cell is inadequate. Therefore, cells are connected together in series to increase the voltage. Several of these series strings of cells may be connected together in parallel to increase the current as well. These interconnected cells and their electrical connections are then sandwiched between a top layer of glass or clear plastic and a lower level of plastic or plastic and metal. An outer frame is attached to increase mechanical strength, and to provide a way to mount the unit. This package is called a "module" or "panel" Figure 1. Typically, a module is the basic building block of photovoltaic systems which deliver the DC electrical power as transform of solar irradiance. But power generated through this module is very much depends on climatic conditions.

Rating of PV Modules

The solar PV modules are rated in terms of their peak power (Wp) output. This is the most important parameter from a system designer's point of view. The Wp is specified by the manufacturer under the Standard Test conditions (STC).

The STC condition refers to the following condition:

- **Irradiation:** 1000W/m^2, AM 1.5 G global solar radiation
- **Module or Cell Temperature:** 25 deg. C
- **Wind Speed:** 1m/s.

But STC is never been the practical situation. This is the fact because solar irradiation is normally less than 1000W/ m^2 and the module temperature is cannot be constant and even very much higher than the STC. These both parameters are location specific and time dependent.[4]

Thus, to have more realistic figure for the possible power output from the PV module, it's performance is defined in two other test conditions: standard operating condition (SOC) and nominal operating conditions (NOC) and under these conditions performance is expressed by different concept of temperature, called Nominal Operating Cell Temperature (NOCT). The NOCT is defined as the temperature reached by a cell in an open circuited module under the following conditions:

- **Irradiation:** 800 W/ m^2
- **Ambient Temperature:** 20 deg. C
- **Wind Speed:** 1m/s
- **Mounting:** Open back side.

The NOCT can be used to give more realistic cell temperature of the module under operating conditions and it's value usually lies between 42 to 52 deg. C and this value is specified by the manufactures of the PV panel. At given ambient temperature the actual module temperature can be given by following equation:

$$Tmod = Tamb + \left(\frac{NOCT-20}{0.8}\right) * Pin$$

Where Pin is solar irradiation in W/ m^2

This Tmod is very important factor which define final power deliver by the PV panel.

I-V and Power Curve

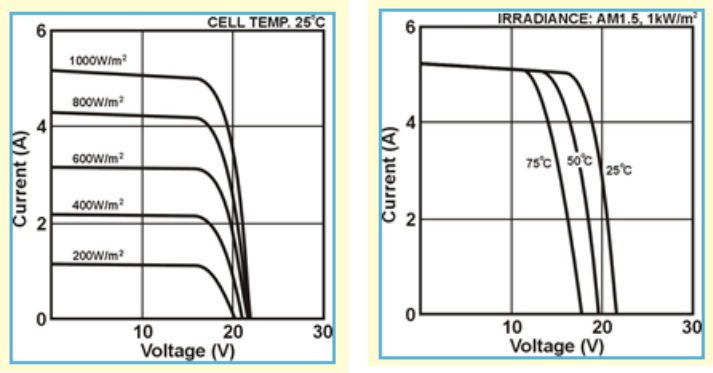

Figure 2: I-V Curve for PV Module

I-V curve express the relation of output voltage vs current delivered by PV panel. From figure 'a', it is very much clear as the current in I-V characteristic of panel is highly influence by solar radiation considering constant cell temperature.

From figure 'b' one can notice as at constant radiation if temperature of cell is varied the output voltage get influence.

As a result of these two facts happening simultaneously in real time scenario the PV peak power output is highly time and location specific.

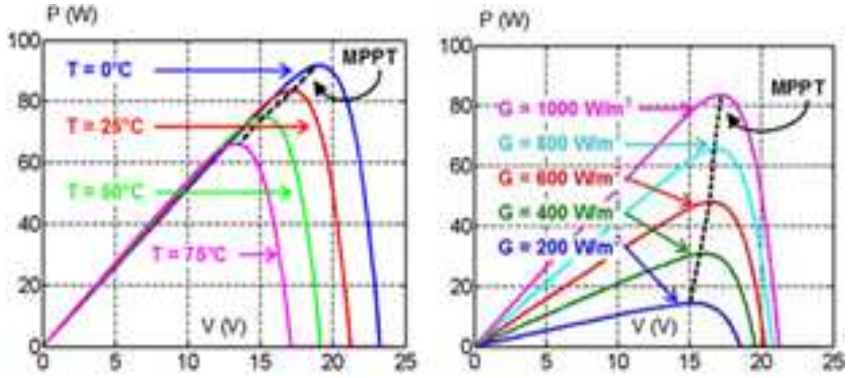

Figure 3: Power Curve for PV Module

In figure 'c', it can be clearly visible as MPPT (Maximum Power point) of the panel is having linear relation with both Solar radiation and Panel Temperature. This is the basic fact on which this paper works on to develop a region specific neural network which can estimate PV module performance at different locations and under different environmental conditions.

NURAL NETWORK

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the connections between elements largely determine the network function. You can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. [4]

Typically, neural networks are adjusted, or trained, so that a particular input leads to a specific target output. The next figure illustrates such a situation. [5]

There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically, many such input/target pairs are needed to train a network.

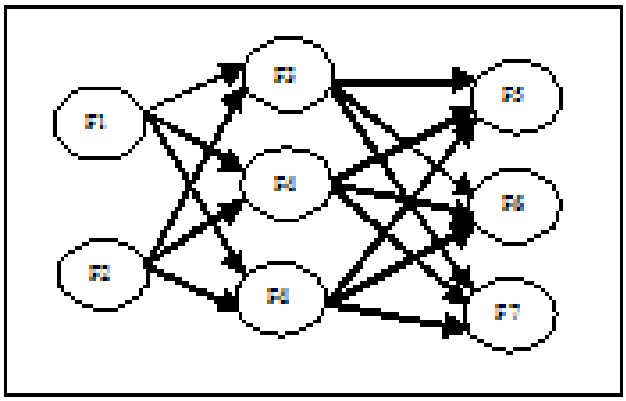

Figure 4: Basic Blocks of Neural Network

NN is actually an data processing system which is consists of a graph representing the processing elements as well as various algorithm that access that graph. This networks can be trained to find relationship between parameters which difficult to find by mathematical model.

SYSTEM ANALYSIS & DESIGN

Collection of Data

The design process of neural network for the system to evaluate performance of PV module based on Location and –Month of the year. First step is to prepare training data. We have defined scope of operation by restricting data for the state of "Maharashtra".

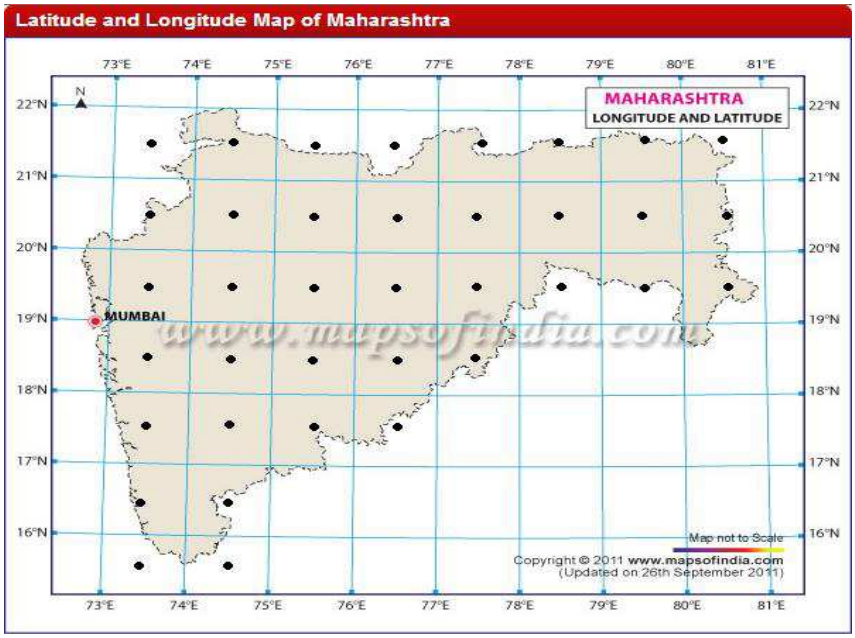

Figure 5: Maharashtra State Map with Data Points [7]

Latitude and Longitude Map of Maharashtra state is divided into 37 cells at interval of 1 deg. of longitude and latitude which is about 111 x 111 km sq. as shown in Figure 5.

Centre of each cell in terms of Longitude-Latitude and Altitude are identified. For each respective center point of cell, month wise data of DAAT (Daytime Average Ambient Temperature), GHI (Global Horizontal Irradiations) and SH (Sunshine Hours) is collected for 20 years [6].

Pre-Processing of Data

- Prepared a Spread Sheet in Excel with Columns as:

Longitude-Latitude –Altitude-JAN-FAB-……..DEC and under each month we have calculated columns as Tmod- Pmpp.

This spreadsheet is prepared for specific PV panel.

In this paper we have consider SHARP make NU series J5 (60 cells) 250 W Monocrystalline silicon photovoltaic modules having [3] data sheet parameter as:

Temperature co-efficient for power: *–0.463 % / °C.[3]*

- Module Temperature: [4]

$$Tmod = Tamb + \left(\frac{NOCT-20}{0.8}\right) * Pin$$

Where,

- NOCT (Nominal Operating Cell Temperature) = *47.5* deg. C [3]
- Pin= (GHI in kW/m2/day)/average sun shine hours.
- Tamb is average day ambient temperature at respective Longitude-Latitude –Altitude month wise.

Pmpp (Module power at maximum power point):

$$Pmpp = Rated\ Wp * (1 - (Temp.co - eff.) * (Tamb - Tmod))$$

In case of SHARP make NU series J5 (60 cells) 250 W

$$Pmpp = 250 * (1 - (-0.00463) * (Tamb - Tmod))$$

Neural Network Architecture

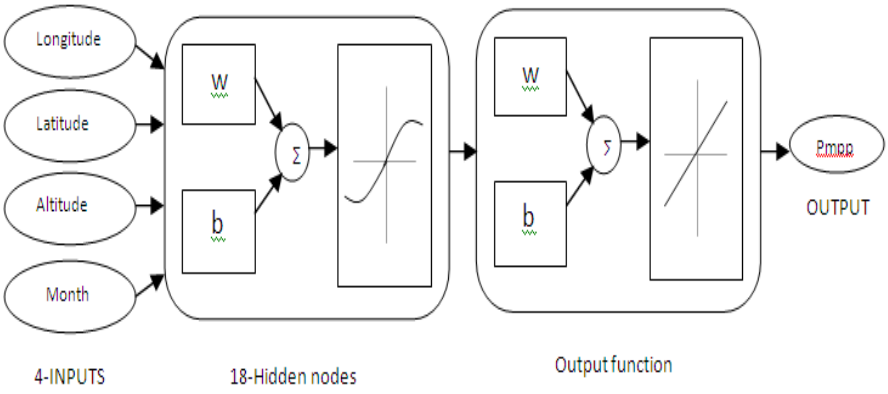

Figure 6: NN Architecture

The network has four inputs as Longitude, Latitude, Altitude and Month and one output as Module Power.

There are 18 hidden layer with weight and biases employing Hyperbolic tangent sigmoid transfer function and one output layer with Linear transfer function.

After a neural network has been created, it needs to be configured and then trained. Configuration involves arranging the network so that it is compatible with problem for with we are interested to get answer form network, as defined by our sampled data. After the network has been configured, the adjustable network parameters i.e. weights and biases need to be tuned, so that the network performance is optimized. Configuration and training require that the network be provided with data that is prepared in our excel sheet as discussed before.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Out of total data 70 % data is used for training and 30 % data is used for testing and validation. Neural network is trained with data collected. Train the network till we get regression near to 1 and error plot show peaks more concentrated near zero as shown in figure.

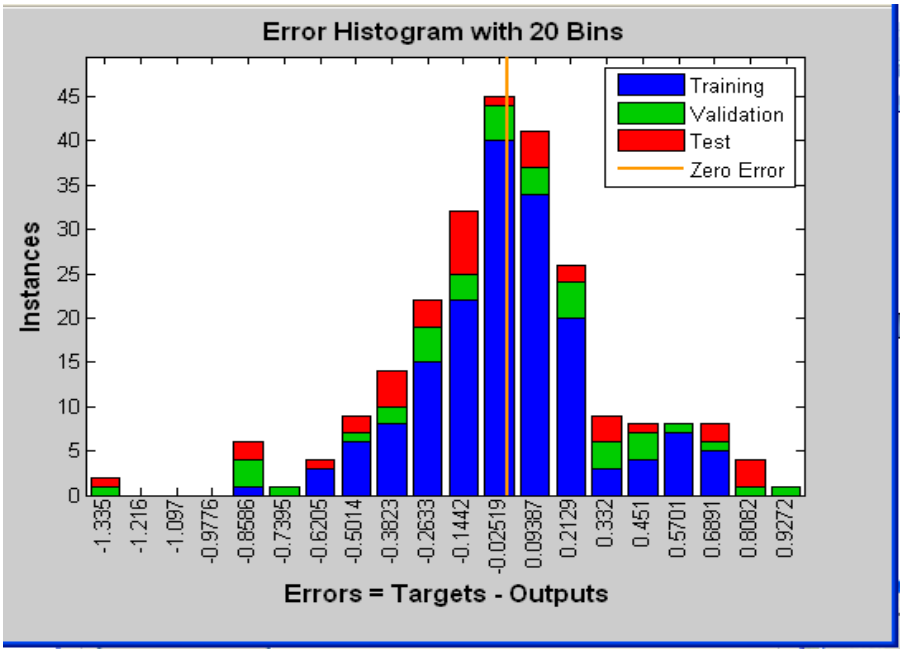

Figure 7: Error Bar Chart

It has been observed that error between predicted and actual reading is minimum.

Performance Evaluation of System

In order to verify the performance of Neural Network four random points within the region in terms of Longitude, Latitude and Altitude are picked up, for which we have calculated values. For respective points we got month wise panel output in Watts as estimated by our neural network, then bar chart is plotted for each location as month wise estimated v/s calculated Pmpp as shown in figure 8

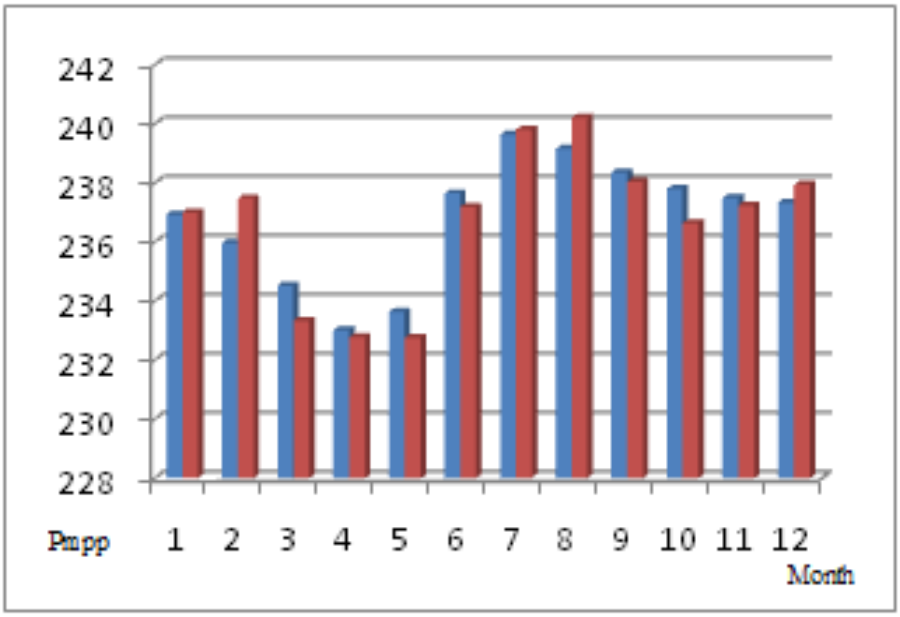

Figure 8: NN Output vs Calculated Values

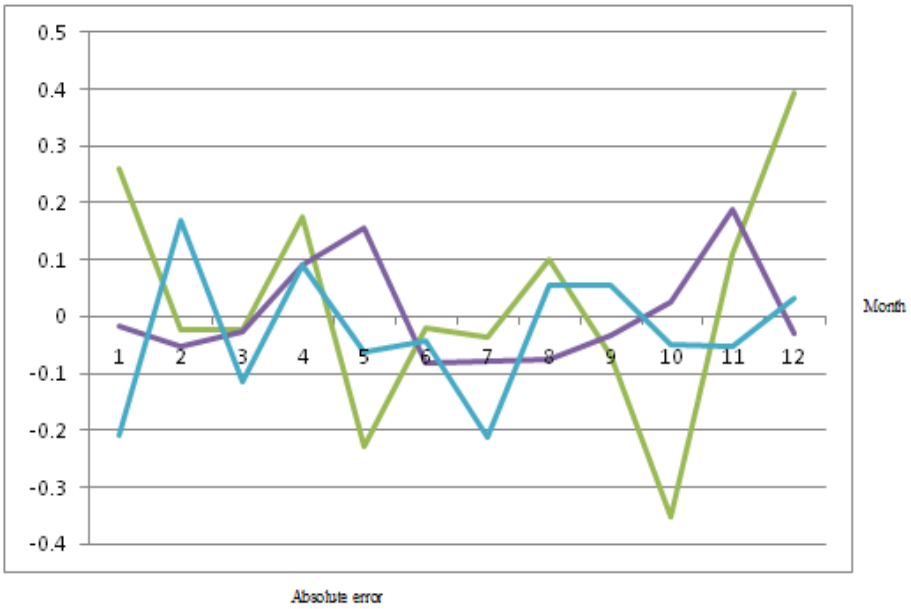

Figure 9: Month Wise Error Plot for Different Location Outputs

The system performance is further evaluated by taking error plot of different location points within the region.

To verify repeatability of the network output is verified against three set of reading on each point observation show close matching of plot profile with calculated values.

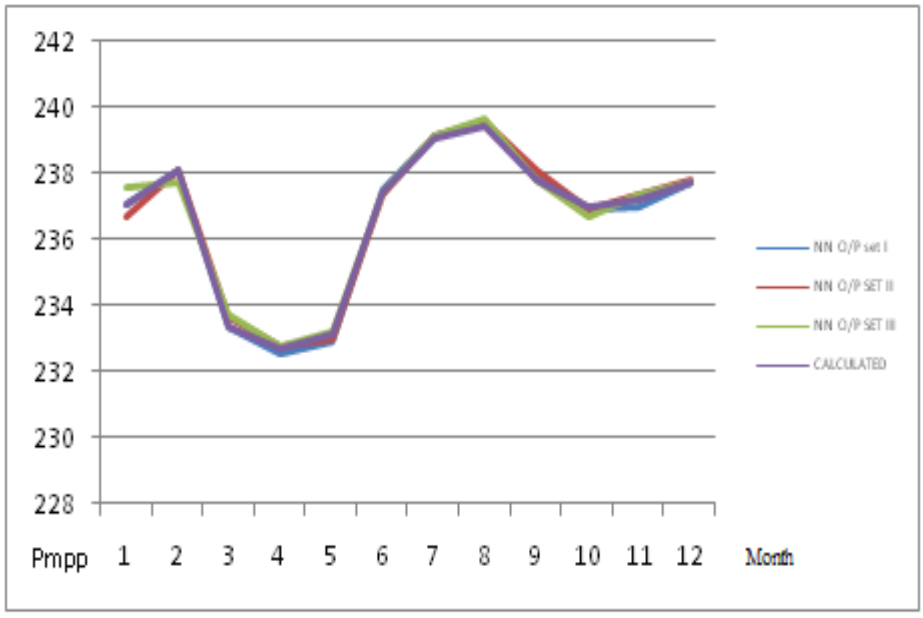

Figure 10: Repeatability Plot

MSE is calculated for each set of estimated data which average out to be less than 0.5. Hence it ensure as NN estimation is quite accurate one.

Observations against different experimentation shows that we have to develop respective networks of each region of relatively uniform climatic condition which ensure more accuracy of the estimation for PV panel performance within the region.

NN based is useful to use, wherein it take inputs as any location in Maharashtra state in terms of its Longitude-Latitude-Altitude then system will reply with month wise plot of Module power at the specified location as shown in figure 11.

Applicability of NN System

Manufacturer can have applicability of this NN system as to evaluate the performance of the module at various location within the region without physically moving panel to that location.

System designer can find it useful while selecting solar module for specific location wherein he can verify the periodic behavior of the panel at the location by this system.

This system has to be trained for respective data of the specified rated PV module and hence for each type of module one has to perform entire exercise of pre-processing of data, training the network and developing system specifically according to module data sheet.

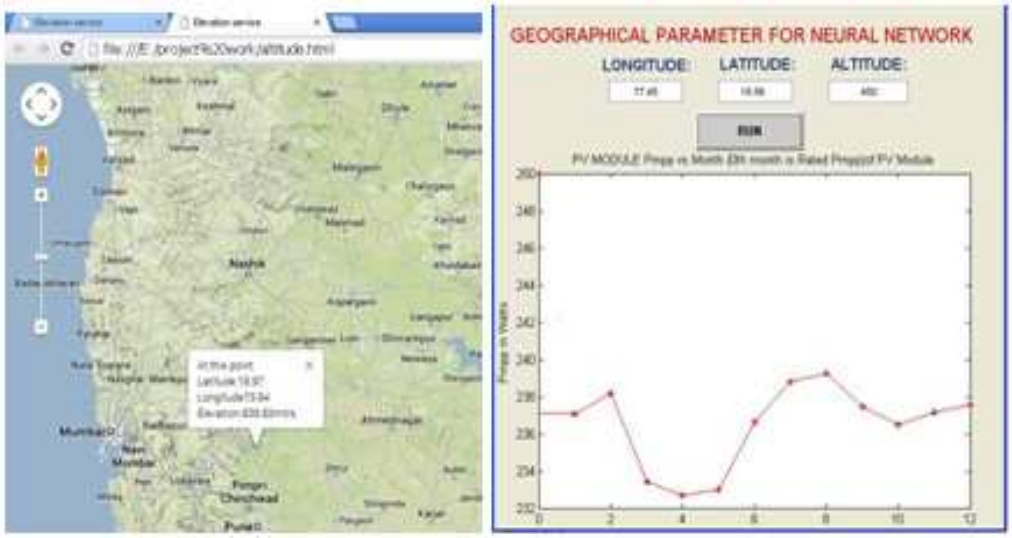

Figure 11: Web Based Application

This system can be proposed to be a web base application wherein user can interact through Google map by clicking at his location of interest, WMS (Web Map Service) will provide all three parameters as Longitude-Latitude-Altitude which will be captured and pass on to server where with Neural Network system will take this input and reply with plot of month wise module power for specified model of PV panel.

Thus by making it web based user friendly application it will be very widely accessible useful tool for system designer and manufacturer.

CONCLUSIONS

- Neural Network based system can be useful to predict complete annual performance of PV module which is Location specific.
- Error is minimum.
- Useful for solar system designers and PV module manufacturers.

REFERENCES

1. Solar PV Energy for Academic Campuses in India A White Paper, Chetan S. Solanki, Department of Energy Science and Engineering IIT Bombay.
2. International Renewable Energy Agency case study 2013 on “Solar Radiation Resource in India”.
3. SHARP make NU series J5 (60 cells) 250 W Monocrystalline silicon photovoltaic modules data sheet.
4. Solar Photovoltaics fundamental, Technologies and application by Chetan Singh Solanki.
5. Neural Network Toolbox user guide by MATLAB.
6. https://eosweb.larc.nasa.gov/sse/
7. www.mapsofindia.com