International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 5 Issue 5|| May 2016 || PP.18-25

Modelling and Prediction of 150KW PV Array System in Northern India using Artificial Neural Network

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ABSTRACT: *In this research work modeling of solar power using feed forward back propagation (FFBP) artificial neural network. In three different ways inputs are given to FFBP to model photovoltaic module power and generated power is approximated .Six month's data is taken i.e. from August 2015 to January 2016.Generated power is obtained at the end. All three show good modeling performance. However second input method shows the better results.*
KEYWORDS*- Solar Radiation, FFBP, PV module, Prediction, Regression*

I. INTRODUCTION

Today one of the main issues faced by the whole world is to meet the energy requirement of a common man as renewable sources are limited and because of luxurious life the consumption of energy is increasing day by day. Thus the focus is on non - renewable energy sources. Basically 3 major non –renewable sources available to us are solar, thermal and wind. Among three solar is gaining more attention. The electricity produced by the sunlight called as solar power. The two major sources from solar energy for electricity generation are Photovoltaic panel and solar thermal [1]. Accurate mathematical modeling is classically used for prediction. With the use of accurate prediction is mathematical and conditional expectations based on past data samples .Also powerful computing system is required for numerical method

An artificial neural network is very similar to human brain. Without using much computational efforts an input output relationship for linear and non linear system using ANN. McCulloch pits introduced the original ANN Previous research shows that prediction of solar radiation using neural networks has been employed both in time and space. Various comparative studies and traditional approaches prove that ANN is more efficient and consumes less time in modeling a very complex system [2]

II. PV SYSTEM DESCRIPTION

The studied PV system is in its first year of installation. The solar panel is installed at The NorthCap University (NCU) located in Gurgaon (NCR Delhi). Large number of solar cells interconnected together that converts sunlight into electrical energy forms photovoltaic module (PV module).

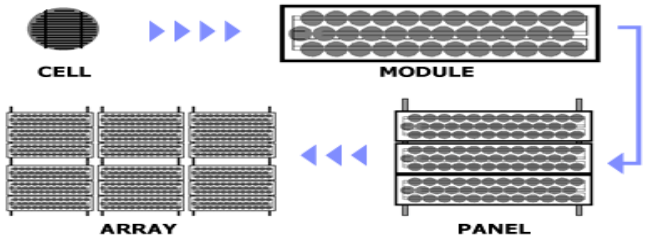


Figure1. Various components of PV system

Total combine power of 150kw is produced by 600 modules of PV system. Each module consists of 60 cells. High efficiency multi crystalline silicon panels are within PV system. The supply of which is transferred to grid. PV system is located at 28.5043ºNorth, 77.0490ºEast of Haryana, Gurgaon.

Parameter	**Specification**
PV module capacity	250 Wp
PV module type	Poly crystalline
Total no of modules	600
No of PV cells per Module	60
Open circuit voltage (Voc)	37.80V
Short Circuit voltage	8.80A
Peak power voltage	30.60

III. METHODOLOGY

III.1Artificial Neural Network

Architecture, training algorithm and activation are main characterization factors in ANN [2]. The architecture describes the manner in which the neuron of neural network is structured. . Architecture consists of an input layer, an output layer and one or more hidden layers in between the two layers [2]. Among different architectures feedforward backpropagation (FFBP) is most common and used for the prediction in the research.

*III.*2Feedforward Backpropagation

A feedforward network can be defined as types of network where information propagate only in forward direction .Two types of feedforward network are there. Single layer feed forward and Multilayer perceptron. Faith O. Hocaoglu et.al [5] used feed forward neural network for hourly solar radiation forecasting. In the research Multi Layer Perceptron (MLP) is used.SaberianH.Hizamet .al [1] used MLP for prediction of photovoltaic power output. He has taken 4 inputs as max temperature, min temperature, mean temperature and irradiance. The most common learning algorithm for feed forward network is back propagation [1]. Few steps are included for the backpropagation algorithms training process .The weights are initialized for the neurons and the measured output is compared with the desired value to calculate the error .In the next steps, on the basis of error weights are changed. This way error is propagated backward to update the weights. [1] Christophe Paoli et .al [4] used MLP for forecasting of preprocessed daily solar radiation.

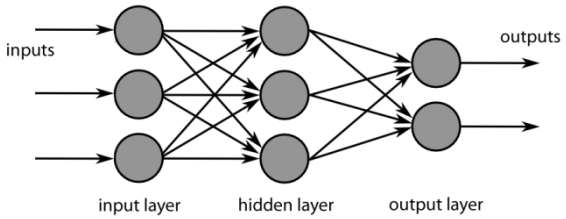


Figure2. Multilayer Feedforward Network

IV. EXPERIMENTAL DATA

For the research work, data taken from solar panels installed at NCU campus. Six months data i.e. from August 2015 to January 2016 is collected from DAQ. Sensor reading and production reading are extracted. In the gap of three hours module temperature and irradiance obtained from sensor reading as shown in Fig.3 and power from production reading shown in Fig.4

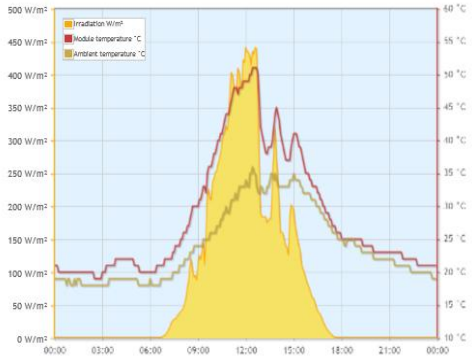


Figure3. Sensor reading from solar panel

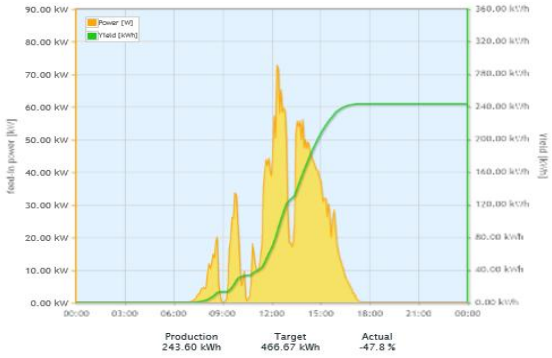
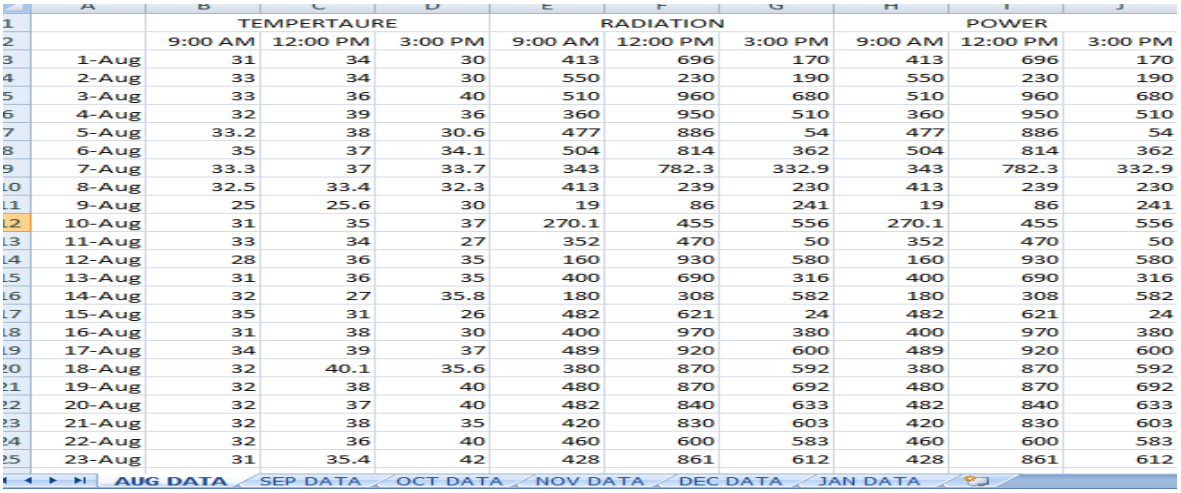


Figure4 Production reading from solar panel

Inputs to ANN are given in three different ways one by one for the prediction and then results are compared to find the best possible method.

IV.1 Original data

The original data i.e. the data that is obtained from solar panel (temperature irradiance and power) are directly fed to the neural network for the prediction of power. For the month of August original data sheet is shown below. In the similar way all six month data sheet is prepared.



		TEMPERTAURE			RADIATION			POWER		
		9:00 AM	12:00 PM	3:00 PM	9:00 AM	12:00 PM	3:00 PM	9:00 AM	12:00 PM	3:00 PM
3	1-Aug	31	34	30	413	696	170	413	696	170
4	2-Aug	33	34	30	550	230	190	550	230	190
5	3-Aug	33	36	40	510	960	680	510	960	680
6	4-Aug	32	39	36	360	950	510	360	950	510
7	5-Aug	33.2	38	30.6	477	886	54	477	886	54
8	6-Aug	35	37	34.1	504	814	362	504	814	362
9	7-Aug	33.3	37	33.7	343	782.3	332.9	343	782.3	332.9
10	8-Aug	32.5	33.4	32.3	413	239	230	413	239	230
11	9-Aug	25	25.6	30	19	86	241	19	86	241
12	10-Aug	31	35	37	270.1	455	556	270.1	455	556
13	11-Aug	33	34	27	352	470	50	352	470	50
14	12-Aug	28	36	35	160	930	580	160	930	580
15	13-Aug	31	36	35	400	690	316	400	690	316
16	14-Aug	32	27	35.8	180	308	582	180	308	582
17	15-Aug	35	31	26	482	621	24	482	621	24
18	16-Aug	31	38	30	400	970	380	400	970	380
19	17-Aug	34	39	37	489	920	600	489	920	600
20	18-Aug	32	40.1	35.6	380	870	592	380	870	592
21	19-Aug	32	38	40	480	870	692	480	870	692
22	20-Aug	32	37	40	482	840	633	482	840	633
23	21-Aug	32	38	35	420	830	603	420	830	603
24	22-Aug	32	36	40	460	600	583	460	600	583
25	23-Aug	31	35.4	42	428	861	612	428	861	612

AUG DATA | SEP DATA | OCT DATA | NOV DATA | DEC DATA | JAN DATA

IV.2 Minimum Maximum Mean Data

Second way in which the input is given is maximum and minimum temperature, mean irradiance and mean power found for each day of whole six months .For the month of august data is shown in the table (1). Similarly for remaining five month minimum maximum and mean data is calculated.

Date	Min Temp	Max Temp	Mean Rad	Mean Power
1-Aug	12	27	260.4	43.75
2-Aug	31	26	214	64.55
3-Aug	24	40	448.12	49.95
4-Aug	25	36	390.4	42.85
5-Aug	25	30.6	294.38	51.75
6-Aug	23.7	34.1	345	46.75
7-Aug	23	33.7	298.24	29.2
8-Aug	25	32.3	187.04	12.475
9-Aug	25	30	83	53.525
10-Aug	26.4	37	271.22	32.925
11-Aug	26	27	182.2	57.775
12-Aug	25	35	348	64.1
13-Aug	26	35	292.6	47.925
14-Aug	24	35.8	229.4	35.7
15-Aug	22	26	233	58.575
16-Aug	22	30	366.6	59.725
17-Aug	26	37	424.6	61.25
18-Aug	25	35.6	378.78	69.45
19-Aug	23	40	418.4	59.85
20-Aug	23	40	406.2	58.625
21-Aug	24	35	385.4	61.925
22-Aug	25	40	347.8	63.15
23-Aug	24	42	400	62.5
24-Aug	24.3	40	454.2	44
25-Aug	23	39.5	462	65.425
26-Aug	25	39.5	427.2	66.25
27-Aug	26	43	452	59.675
28-Aug	24	40	391.8	65.1
29-Aug	24	42	433.6	47.625
30-Aug	23	45	409.2	57.225
31-Aug	24	42.4	438.8	62.25

Table1. Maximum Minimum and Mean Data For the month of August

IV.3. Normalized data

Data obtained i.e. temperature, irradiance and power is normalized to [0 1] using equation (1) on monthly basis

$$y_i^* = \frac{y_i - y_{min}}{y_{max} - y_{min}} \qquad (1)$$

Where y_i is the original data value of particular month y_i* is the normalized value .y_{min} is the minimum value and y_{max} is maximum value. The time period is six months. y_{min} is the minimum value in particular month and y_{max} is the maximum value in the particular month . Normalized value for the month of August is shown in table (2). In the similar way remaining five months normalized data is calculated

Date	Normalized Temp	Normalized Irradiance	Normalized Power
1-Aug	0.685	0.707	0.841
2-Aug	0.685	0.219	0.373
3-Aug	0.742	1	1
4-Aug	0.828	0.795	0.822
5-Aug	0.8	0.827	0.87
6-Aug	0.771	0.728	0.785
7-Aug	0.771	0.735	0.747
8-Aug	0.657	0.169	0.189
9-Aug	0.428	0	0
10-Aug	0.714	0.534	0.635
11-Aug	0.685	0.496	0.523
12-Aug	0.742	0.778	0.878
13-Aug	0.742	0.565	0.8411
14-Aug	0.485	0.227	0.56
15-Aug	0.6	0.503	0.654
16-Aug	0.8	0.813	0.94
17-Aug	0.828	0.824	0.897
18-Aug	0.857	0.724	0.841
19-Aug	0.8	0.724	0.915
20-Aug	0.771	0.698	0.869
21-Aug	0.8	0.689	0.813
22-Aug	0.742	0.485	0.858
23-Aug	0.714	0.716	0.887
24-Aug	0.742	0.753	0.887
25-Aug	0.828	0.778	0.822
26-Aug	0.828	0.761	0.869
27-Aug	0.857	0.798	0.878
28-Aug	0.885	0.729	0.813
29-Aug	0.885	0.771	0.841
30-Aug	0.885	0.733	0.831
31-Aug	0.885	0.745	0.871

Table 2 Normalized data for the month of August

Fig.5 shows how the power output varies with temperature. It is found that temperature and power are similar in shape but different in amplitude

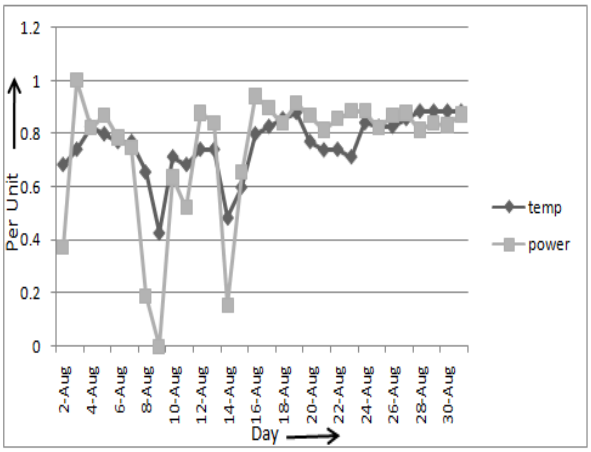


Figure 5. The per unit curves of power output and temperature

Fig 6 shows how output power is related to irradiance. It is found that irradiance and power are essentially similar [3] .Solar irradiance and power are directly proportional i.e. when irradiation increases, the power output of PV system increases and vice versa

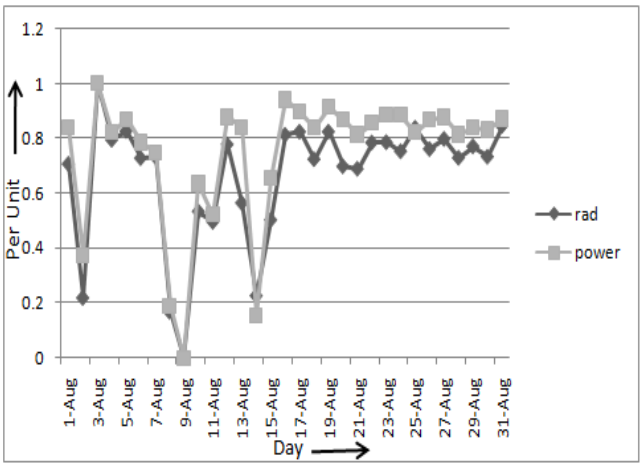


Figure 6 The per unit curves of power output and irradiance

V. RESULTS AND DISCUSSION

All the three different inputs are imported into the MATLAB workspace one by one. Using the command nnstart neural network opens in MATLAB and prediction process is performed Prediction results are described below. The three implementation methods are compared. The regression values obtained from the three methods are shown in table. Fig 7.a, 7.b, 7.c represent the regression of calculating data and the real..It can be seen in these figures, the measured error is very low.

Input type	Regression
Original Input	0.93036
Maximum -Minimum	0.94566
Normalized	0.93172

Table3. Regression values from the three types of input

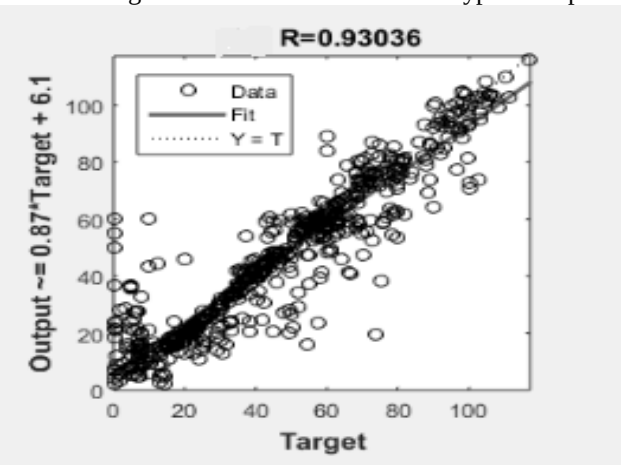


Figure 7.a. FFBP regression of error for original data

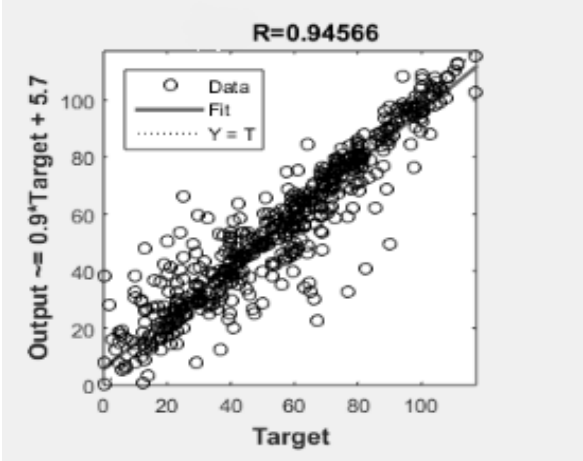


Figure 7.b FFBP regression of error for maximum minimum mean data

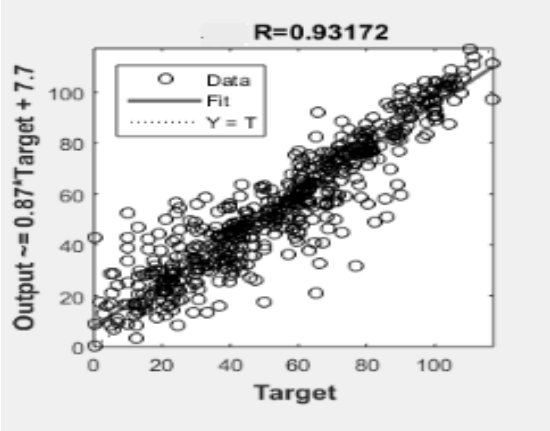


Figure 7.c. FFBP regression of error for normalized data

Fig 8.a, 8.b shows the result obtained from original data and value for the months of August and September at 12 pm is plotted. Predicted and actual value is compared. . Graph is plotted for overall six month as shown in Fig 8.cit can be seen that there is very small difference between the actual and predicted data

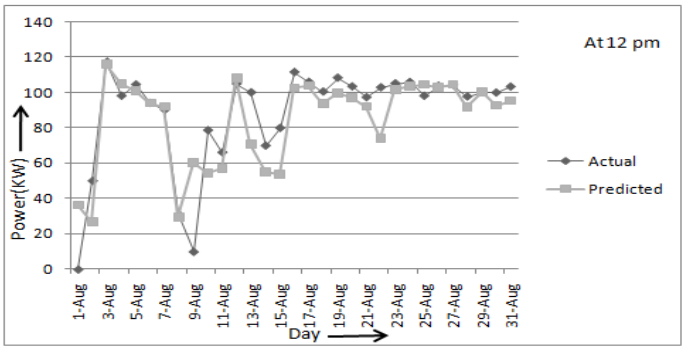


Figure 8.a. Results for actual data and predicted data for month of August

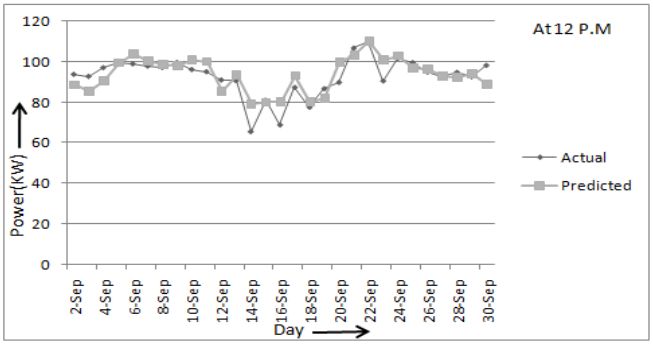


Figure8.b. Results for actual data and predicted data for month of September

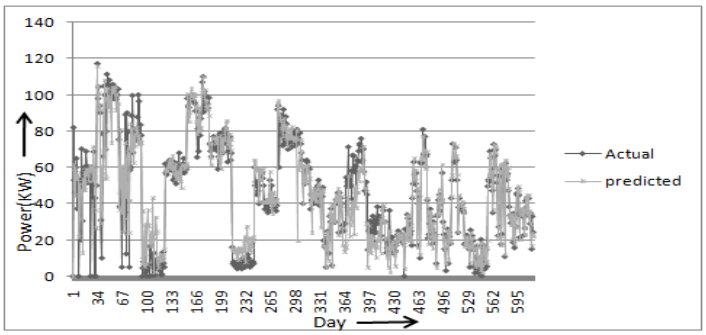


Figure 8.cover all six month results for actual data and predicted data

Fig9.a, 9.b shows the results obtained through maximum and minimum value. For the month of August and September and overall six months graphs are plotted between the actual and predicted value. There is very little difference between actual and predicted value and there is very similarity between the two values.

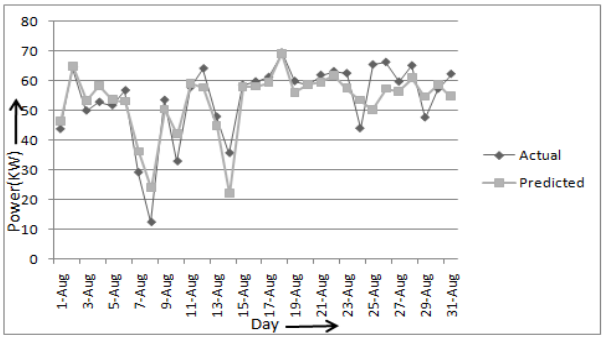


Figure 9.a. Results for actual data and predicted data for month of August

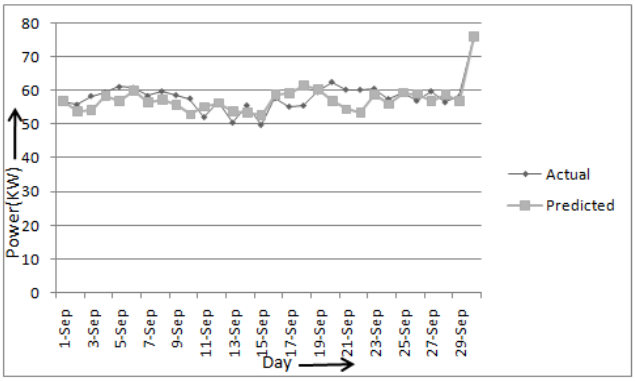


Figure 9.b. Results for actual data and predicted data for month of September

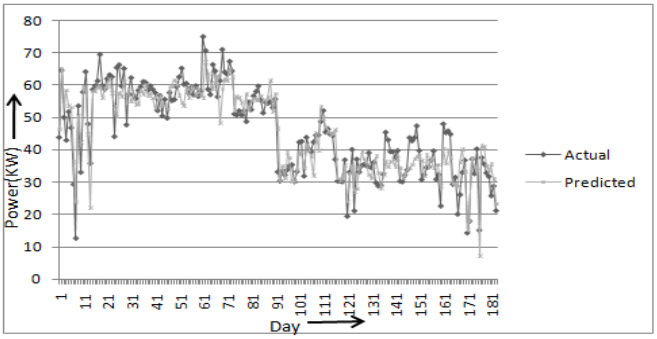


Figure 9.cover all six month results for actual data and predicted data

Normalized results are shown in the Fig 10.a,10.bThe graphs for the month of August and September are plotted between actual and predicted value .Also overall six month graphs is plotted. Graphs show the good prediction results.

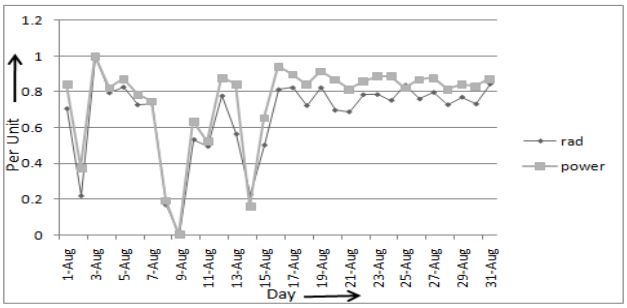


Figure 10.a. Results for actual data and predicted data for month of August

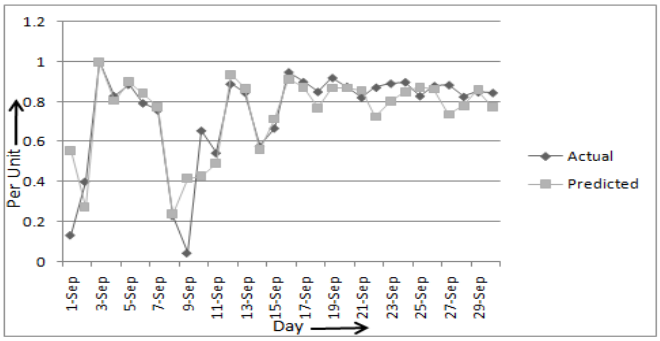
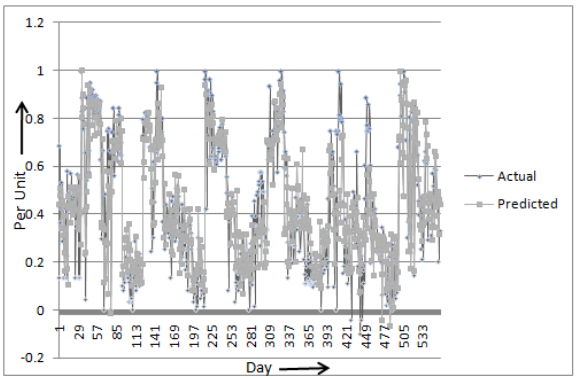


Figure 10.b. Results for actual data and predicted data for month of September



Figur10.c. Over all six month results for actual data and predicted data

VI. CONCLUSION

Prediction of output power for photovoltaic module is required for accuracy in power planning. In this paper actual output power is taken from the solar panels installed at NCU campus .Thereafter, temperature, irradiance and output power have been used for training FFBP neural network with three different ways of inputs. All the three types show the good modeling results. Regression error for real data and predicted data is very low for all the three ways. Among three maximum minimum input gives the better performance.

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