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Improve Short Term Load Forecasting Using Artificial Neural Network by Incorporating Solar PV generation

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Abstract: *Incentive, eco-friendly and cost benefit of photovoltaic are resulting in large amount of roof top solar PV systems being installed in Gujarat. The effect of high penetration of solar PV is that the short term load forecasting result are becoming less reliable. This paper presents the incorporation of photovoltaic generation in short term load forecasting carried out on 11kv 'shivaji circle' feeder of 66kv sardarnagar GETCO substation, Bhavnagar, Gujarat. Artificial Neural Network is used. Data for the month of 15th February to 15th June is taken for network training, testing and forecasting. Matlab is used. This gives load forecast one hour ahead of time.*

Keywords: *Short-term load forecasting, Artificial Neural Network, Photovoltaic Generation*

1. INTRODUCTION

Various Short term load forecasting methods are available like similar day approach, regression approach, Time series analysis, artificial neural network, Expert system, Fuzzy logic, Support vector machine. [1] Best features of Artificial Neural Networks over conventional network are self-adjustment of their weight to minimize the mean square error; constitute distributed-associative memory and hence fault tolerant; learn by example.

Selection of the Artificial Neural Network model architecture depends on the problem to be solved. The architecture includes number of layers, number of neurons within each layer, number of input variables, number of output variables and transfer function for hidden layer neuron and output layer neuron[2]. Transfer function in the Artificial Neural Network maps the input variables to output variables. Transfer function is the key element to invoke the nonlinear relation between input variables and output variables. The architecture feed forward neural network is used.

Short term load forecasting model for solar PV generation is prepared using Artificial Neural Network. [3]

To incorporate solar PV generation in short term load forecasting various methods are available. Two methods are discussed here.

Error Correction Model:
In this method ex post adjustments of load forecast is done to account for forecasted value of solar photovoltaic generation. On sunny days, load forecast is adjusted downward and in cloudy days, load forecast is adjusted upward. The advantages of this method is existing load forecast model can be used without any change and needed is to design forecasting model for solar PV generation.

Model Direct:
In this method the solar PV generation is taken as one of the input variable like other input variables Time, Day of the week, weather etc. The past few month data record of solar PV generation is necessary.

In this paper Error correction model is used to improve short term load forecasting using artificial neural network by incorporating solar PV generation.

Data Formulation:
The data of last one year is taken for study purpose. Data from 16th February 2019 to 15th June 2019 is considered as summer season. Data from 16th June 2019 to 15th October 2019 is considered as monsoon season. Data from 16th October 2019 to 15th February is considered as winter season. As the hourly data is available at substation the load forecasting model is prepared to predict one hour ahead of time load. In this paper Data from 16th February 2019 to 15th June 2019 is taken for network training, testing and validation.

Load data is taken from 66kv sardarnagar GETCO substation, Bhavnagar, Gujarat.
Solar PV generation data of 11 kv Shivaji circle feeder is taken from solar metering and bidirectional metering data available at Hill Drive subdivision office, Bhavnagar.
Total installed capacity of solar PV generation of this feeder is taken from Hill Drive subdivision office, Bhavnagar.

Mathematical Model:

$X_{t+1} = f\,(X_{t-24}, T, D, S) \pm f\,(Y_{t-24}, T, D, S)$

X_{t+1} = Forecasted load one hour ahead of time

X_{t-24} = Neural Network training data of last four month load on feeder.

Y_{t-24} = Neural Network training data of last four month solar PV generation.

T = Hour of the day=(1,2……..24)

D = Day of the week{ sun=0,mon=1,tue=2,wed=3,thus=4,fri=5,sat=6,sun=7}

S = Season (summer=1, Winter=2, Monsoon=3)

Data Scaling Methods:

Before presenting data to the neural network it is necessary to normalized the data within closed unit interval [0, 1] or [-1, 1]. [4]

Input data can be normalized and output result can be renormalized using following equations.

$$\text{Normalized value} = \frac{\text{Actualvalue} - \text{Minimumvalue}}{\text{Maximumvalue} - \text{MinimumValue}}$$

Renormalized value= Output result (Maximum Value-Minimum value) + Minimum value

RESULT:

Neural Network model (Short Term Load forecasting for load data)

Neural Network	: Feed forward type
Training/Learning Algorithm	: Back propagation
Neural Network connection	: 4:9:1
Transfer function for hidden layer	: TANSIG
Transfer function for output layer	: PURELIN
Performance function	: MSE

Neural Network model (Short Term Load forecasting for solar PV Generation)

Neural Network	: Feed forward type
Training/Learning Algorithm	: Back propagation
Neural Network connection	: 4:8:1
Transfer function for hidden layer	: TANSIG
Transfer function for output layer	: PURELIN
Performance function	: MSE

In this Error Correction Model approach the data used is of summer so the output result of the forecasted load of solar PV generation is adjusted downward.

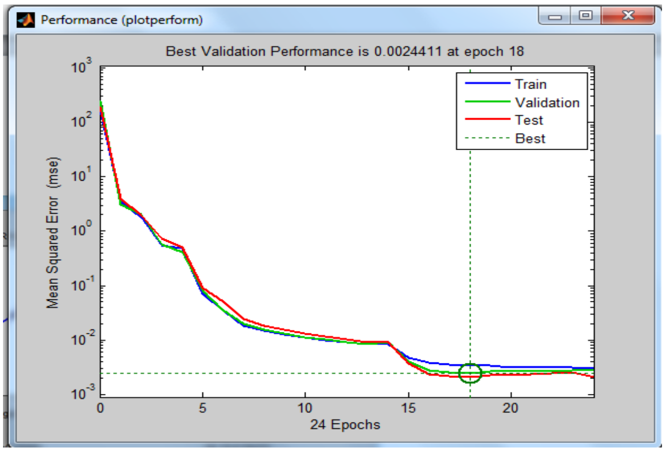

Fig. 1 Best validation performance of solar PV generation at epoch 18.

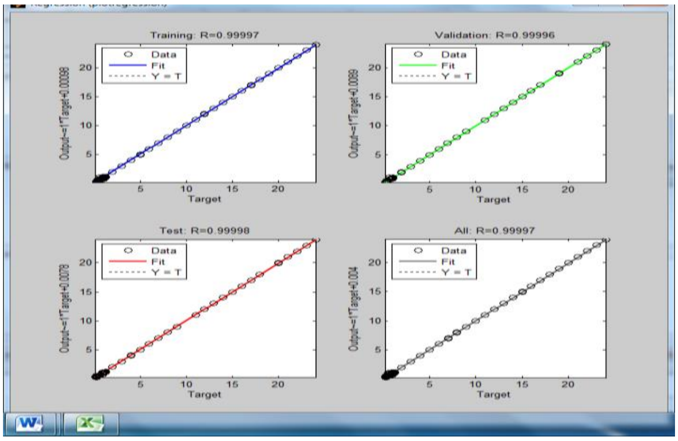

Fig. 2 Regression plot of solar PV generation.

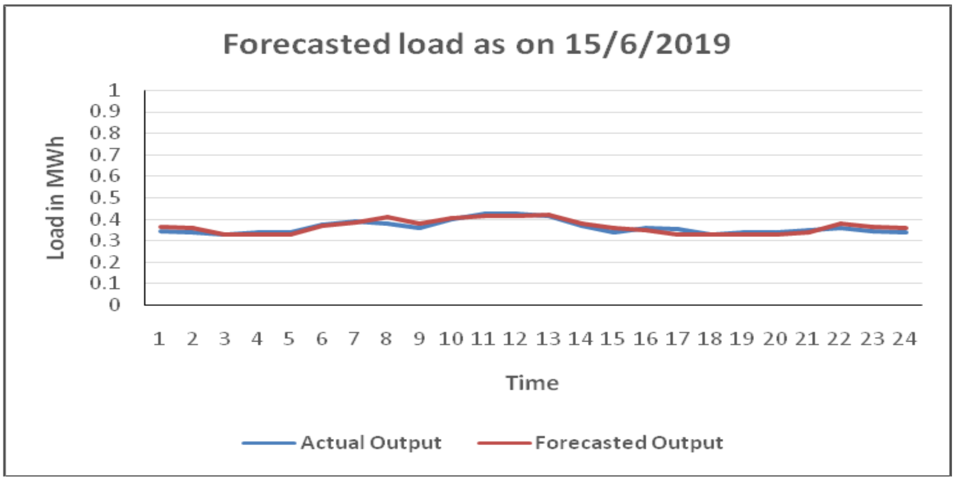

Fig. 3 Actual load and forecasted load incorporating solar PV generation as on 15/6/2019

DISCUSSION:

Load forecasting problem become more complicated as deeper penetration of solar PV generation in existing feeders. This study set out to determine load forecast accuracy of existing load forecast models by incorporating forecast of solar PV generation. Out of two approaches for incorporation of solar PV generation in load forecast, Error correction model is used for study purpose. The best part of this approach is that existing load forecast model can be used without any change and needed is to design forecasting model for solar PV generation. The fact that the results vary by the season therefore three main season's summer, monsoon and winter is taken as one of the input variable.

This improved load forecasting model presented in this paper will result in benefit to the company to reduce the cost of grid regulation required due to forecast errors. By reducing mean absolute percentage error by just 0.1% the company can save millions per year.

CONCLUSION:

The optimal structures of Feed Forward Neural Network for obtaining minimum forecasting error is,

Neural Network model

Neural Network	: Feed forward type
Training/Learning Algorithm	: Back propagation
Neural Network connection	: 4:9:1(Short Term Load forecasting for load data)
	: 4:8:1(Short Term Load forecasting for solar PV Generation)
Number of Hidden layer	: 1
Transfer function for hidden layer	: TANSIG
Transfer function for output layer	: PURELIN
Performance function	: MSE

With this type of structure, the error obtained is minimized. The error depends on several factors such as homogeneity in data, Choice of model, Network parameters and finally type of solution. It is observed that predicted values are in good agreement with exact values and the predicted error is very less, within 3%.

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