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Electric Forecasting using Nature Inspired Optimization Techniques

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Abstract*: *Now a day, there exists huge competition among power industries in terms of fulfilling various customers' electrical needs. Reliable and quality power supply is no doubt a basic need for all power consumers. Moreover, planning & operation engineers also targets for proper unit commitment, economic power dispatch, etc., and highly depend upon good power system planning. Therefore, Electric Forecasting (EF) is a major criterion for power engineers. In this manuscript, Artificial Neural Network (ANN), being a well established tool for modeling non-linear and black box systems, is used to forecast hydro generation power plant, energy met and peak demand of India.

Furthermore, in this competitive world, ANN model is further optimized using genetic algorithm (GA) and particle swarm optimization (PSO) to explore accurate forecasting model with minimal amount of error. These optimization methods explore highly diversified search area, resulting in more accurate forecasting results in comparison to ANN when trained with standard back propagation training algorithm.

Keywords : Artificial neural network, electric forecasting, genetic algorithm and particle swarm optimization.

I. INTRODUCTION

Electricity is one of all the best technological innovations of humanity. It becomes dependency of mankind. The population of developing countries is an increase day by day which also increases electricity demand. Power systems in developing countries has faced many major problems i.e. an insufficient power generation, interrupted & lack of quality power supply, etc., therefore electricity demand is not fulfill as required. The ability of accurate forecasted load is required to overcome from all major problems. Electric forecasting (EF) plays a very important role in electric system. Short-term electric forecasting (STEF) is a technique employed by electricity providing firms to predict the electricity requirement to satisfy demand and supply equilibrium [1].

There are many methods utilized for electric forecasting in the past years. The conventional methods i.e. regression analysis, statistical, time series, etc. has been earlier used. These methods are used when the system are not complicated but day by day load profile has shown very complex behavior due to which classical models are not giving good results. In the past decades, fuzzy logic, expert systems, ANN and intelligent optimization techniques, i.e., PSO & GA are widely used [2].

Among all artificial neural networks (ANNs) have gained more attention of the researchers. ANN is non-parametric model which does not required higher background of statistics. The major advantage of using ANN is it can train large amount of data sets. It has huge number of units and layers that achieve high level of learning with low supervision [3]. Feed Forward Neural Network (FFNN) is commonly used for STEF. But FFNN learning rate is so slow so sometimes it is not employed for STEF. GA is primarily a discrete technique that is also used for combinatorial problems, rapid speed of convergence and capability to improve prediction accuracy of model [4]. Another technique, PSO is quite suitable for various problems with many local minima, where gradient information is not readily available. It can be easily implemented and there are very few parameters to adjust [5]. Its convergence speed is faster and prediction of accuracy is also better than FFNN and GA.

TABLE-1 Various Hybrid Forecasting Approaches

Forecasting model/ approach	Year
kernel-based forecasting [6]	2012
PSO based fuzzy model for distribution systems forecasting [7]	2013
Hybrid methodology for short-term load forecasting [8]	2014
A Hybrid algorithm for power prediction [9]	2017
GA-based non-linear AR prediction for load and wind speed [10]	2018
PSO-SVM based forecasting [11]	2019

ANN has various advantages over conventional methods i.e. capability of fault-tolerance, non-linear modeling, etc. [12]. In this paper historical electric data of Energy Met (MU), Hydro Generation (MU), and Peak Demand (MW) of India is used to develop forecasting models. ANN model is used for electric forecasting which is further optimized by GA and PSO. Both the optimization techniques have improved prediction accuracy. Data is trained using Levenberg-Marquardt algorithm for electric forecasting (STEF). The proposed model is applicable for different load i.e. linear and non-linear loads. Additionally, for testing accuracy rate of model mean absolute percentage error (MAPE) is utilized. MAPE is the better measure performance evaluation [13]. There are various factors which affects load forecasting i.e. demographical, metrological, econometric, etc [14].Section II discussed about case study. The brief descriptions of ANN, GA, PSO architectures and suitable training method used for developing forecasting models are discussed in Section III.

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All the comparatively forecasting results of hydro generation (million units) power plant, energy met (million units) and peak demand (mega watt), India are discussed in Section IV. The results are summarized and analyzed in Section V.

II. CASE STUDY UNDER CONSIDERATION

The daily electric data of India has been collected from 01 April, 2012 to 31 July, 2018 of various profiles i.e. hydro generation (in million units) of a power plant, energy met (in million units) and peak demand (in mega watt) [15]. An ANN methodology is used for developing forecasted model and it is further optimized by GA and PSO for better accuracy. The first 2297 days employed for training & validation purposes and left days is employed for testing. The actual variation of various data profiles is shown in Figs. 1-3.

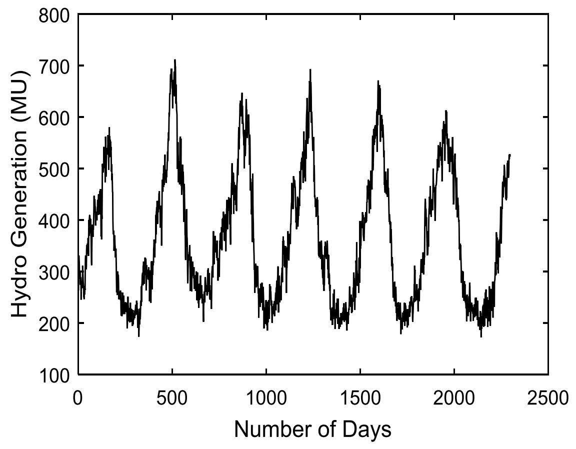

Fig.1. Actual Hydro Generation (MU) data of India

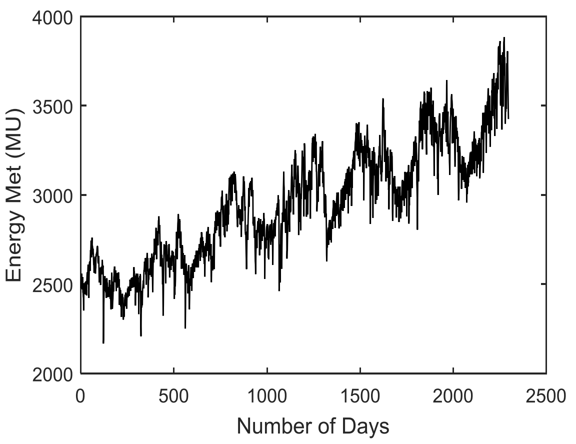

Fig.2. Actual Energy Met (MU) data of India

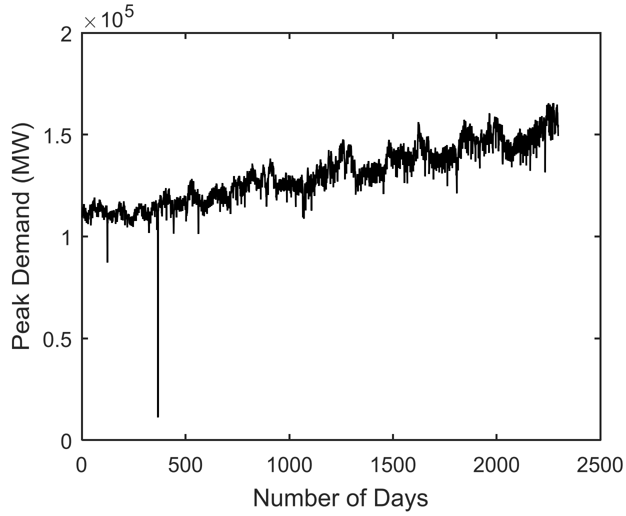

Fig.3. Actual peak demand (MW) data of India

III. ARTIFICIAL NEURAL NETWORKS (ANN)

ANN was first developed in 1943. An artificial neural network is influenced by biological neural network. It consists of multiple nodes. These nodes are interconnected with another and have their own weights. These nodes receive information and gives desired output. If desired output is not received then ANN has capability to adjust the weights. It is a technique to simulate the network of neurons in such a manner so that the computer will be ready to learn things and make decisions like a human brain. It has various applications other than forecasting i.e. pattern recognition, clustering, system identification, etc. [16].

A. Feed Forward Neural Network (FFNN)

It is unidirectional network which don't have any feedback loops. The general architecture of FFNN is shown in Fig.4. To develop forecasting model six inputs i.e. I_{m1}, I_{m2}, I_{m3}, I_{m4}, I_{m5} and I_{m6} and 1 output is taken. According to this, 6-20-1 structure of ANN is selected i.e. 6 input neuron, 20 hidden layer neurons and 1 output. All hidden neurons utilize sigmoid activation function and input & output layers utilize linear activation function. W_{1n} and W_{2n} are the weights of the hidden and output layers [17].

B. Training Patterns for ANN

The developed forecasting model is trained using Levenberg-Marquardt algorithm, i.e., a well known and efficient error back propagation algorithm. Proper training data sequence is must to develop a good forecasting model. To forecast the energy E(t), at time t, six inputs are E(t-k), where, k=[1,7,14,21,28] and D(t), denoting day type parametric value, i.e., value corresponding to Sunday, Monday, etc. at k^{th} day. E(t) is received from the output.

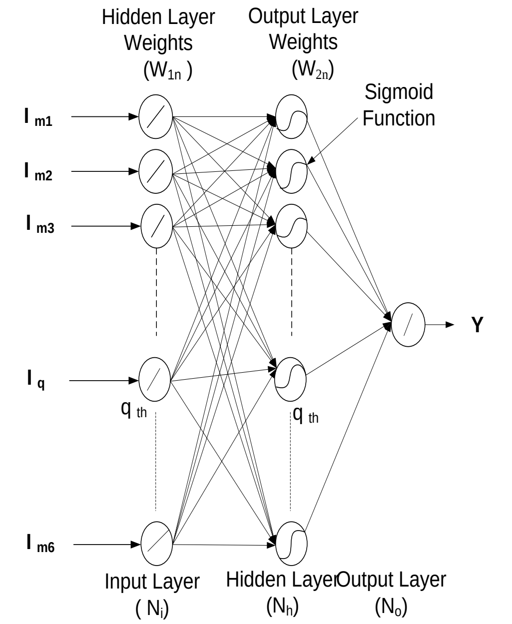

Fig.4. General architecture of feed forward neural network

C. Performance Calculation

MAPE is utilizes for testing accuracy for developed forecasting. It can be calculated by

$$MAPE = \frac{1}{M}\sum\frac{|A_E - F_E|}{A_E} * 100 \qquad (1)$$

In (1), M is forecasted values to calculate error, A_E is actual value and F_E is forecasted value corresponding to actual value [18].

IV. OPTIMIZATION TECHNIQUES

GA and PSO are AI-based optimization techniques which has the capability to improve prediction accuracy of model.

A. Genetic Algorithm (GA)

Genetic Algorithms (GAs) are algorithm that is influenced by Charles Darwin's theory of natural evolution. In this we have a problem with many possible solutions and recombination of solutions produce new generation, this procedure is repeated various times. The optimization procedure runs in three steps, viz., (i) generation, (ii) crossover, and (iii) mutation. In this way, better solutions over generations are received; until stopping criterion is reached [19].

B. Particle Swarm Optimization (PSO)

It is influenced by social behavior of bird flocking or fish schooling and developed by Dr. Eberhart and Dr. Kennedy in 1995. It is implemented with a population which selected random solutions and updating generation by searching optima. It has a solution which is also called particles. Every solution keeps watching their coordinates in the problem which gives best solution. Best solution is obtained with best fitness. Here, the main advantage is that there are it has fewer parameters, need to be adjusted. It is computationally economic than other methods and can be applied to variety of applications [20].

V. RESULTS AND DISCUSSIONS

In this manuscript short-term electric forecasted models of hydrogenation (millions units) of power plant, energy met (million units) and peak demand (mega watt) of India are developed using ANN. Further, it is optimized by GA and PSO techniques to achieve improved forecasted models. The forecasting days are fourteen days

The actual & forecasted data and MAPE of various data profiles are shown here and it is found that PSO is better in comparison to ANN and GA because obtained forecasted data of various data profiles are much close to actual data and obtained MAPE is also minimum which gives better forecasting accuracy.

A. Artificial Neural Network (ANN) Results

The structure of ANN model is 6-20-1 which implies 6 input neurons (N_i), 20 hidden neurons (N_h) and 1 output neuron (N_o). The actual and forecasted results of various data profiles using ANN are shown in Figs. 5-7 respectively. The MAPE obtained is also shown in TABLE 2.

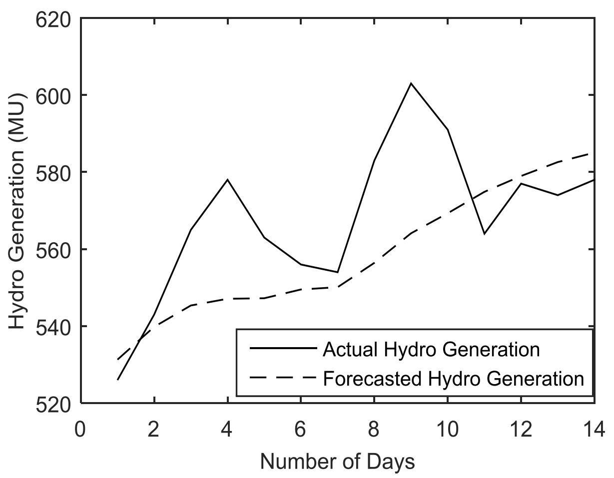

Fig.5. Actual and forecasted data of hydro generation (MU)

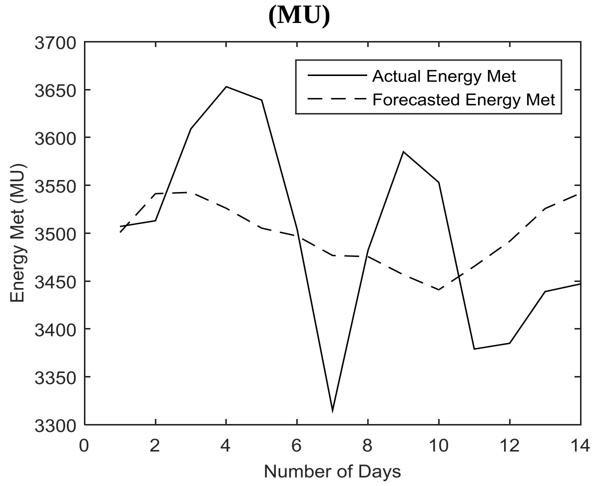

Fig.6. Actual and forecasted data of energy met (MU)

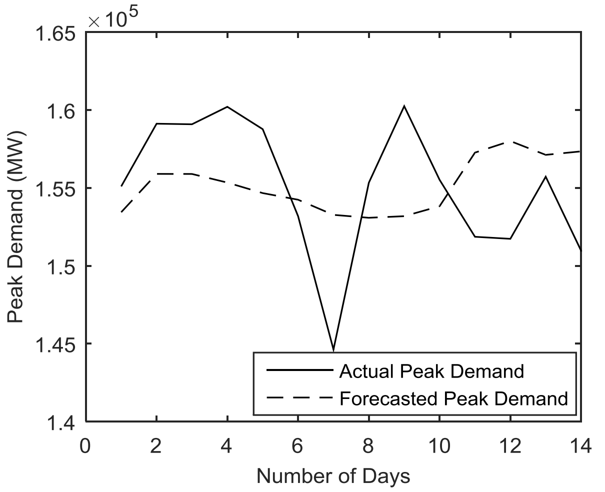

Fig.7. Actual and forecasted data of peak demand (MW)

B. Genetic Algorithm (GA) Results

GA has rapid speed of convergence and capability to improve prediction accuracy of model due to which it is far better than ANN. The actual and forecasted results of various data profiles using GA are shown in Figs. 8-10 respectively The MAPE obtained is also shown in TABLE 2 and minimum error is found by using GA.

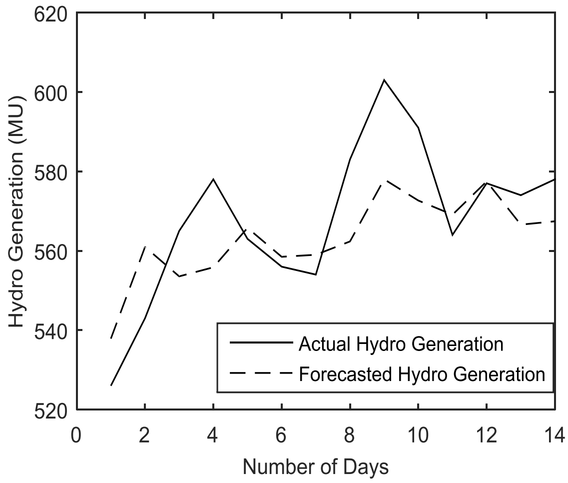

Fig.8. Actual and forecasted data of hydro generation (MU)

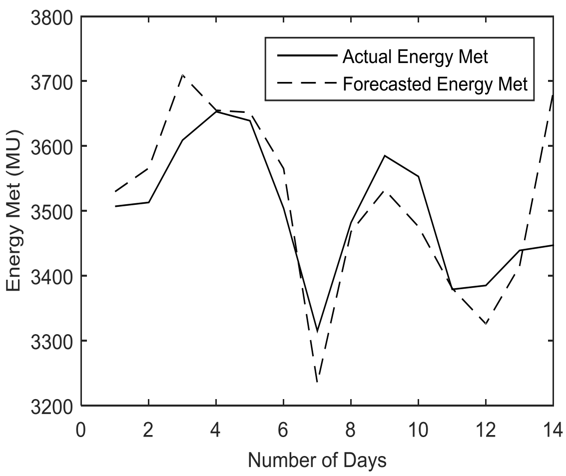

Fig.9. Actual and forecasted data of energy met (MU)

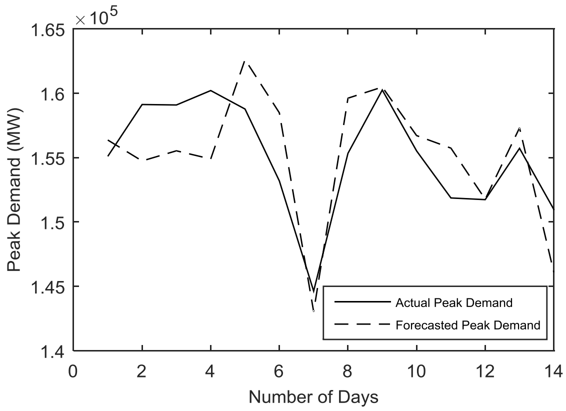

Fig.10. Actual and forecasted data of peak demand (MW)

C. Particle Swarm Optimization Results (PSO)

The actual and forecasted results of various data profiles using PSO are shown in Figs. 11-13. The MAPE obtained is also shown in TABLE 2 and minimum error is found by using PSO in comparison to GA.

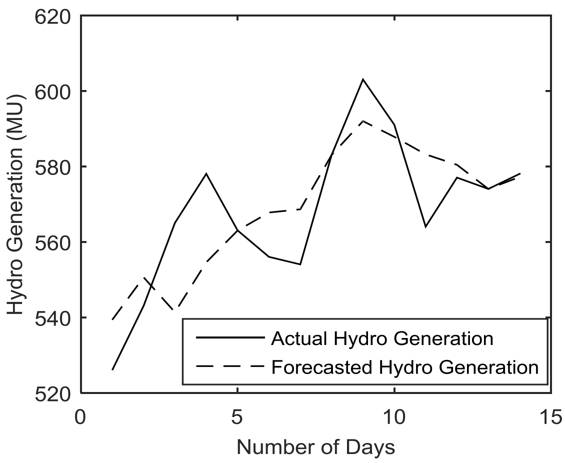

Fig.11. Actual and forecasted data of hydro generation (MU)

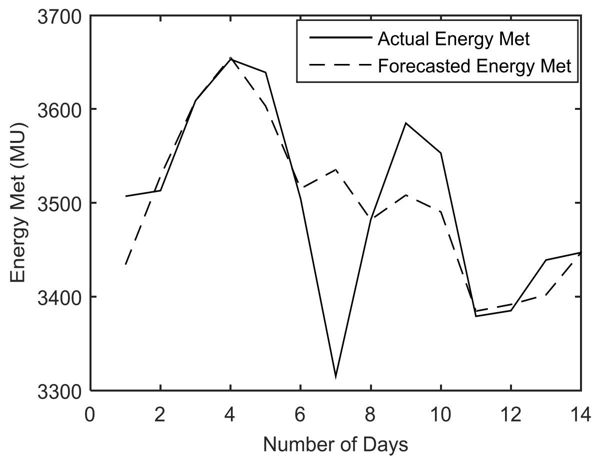

Fig.12. Actual and forecasted data of energy met (MU)

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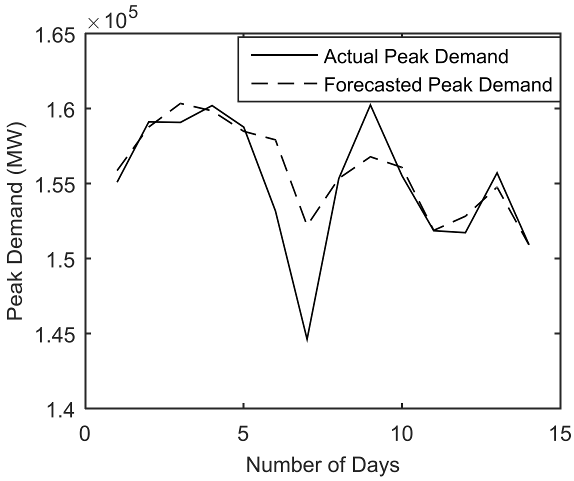

Fig.13. Actual and forecasted data of peak demand (MW)

TABLE-2: MAPE comparison calculated for various ANN-based Forecasting Models with different Data Profiles

S. No.	Data Profile	MAPE		
		BP	GA	PSO
1.	EM	2.4122	1.6373	**1.1336**
2.	HG	2.7667	2.0111	**1.6728**
3.	PD	2.7240	1.8999	**1.0094**

EM=Energy Met (MU); HG=Hydro-Generation (MU); PD=Peak Demand (MW); BP= Error Back Propagation Training Algorithm

TABLE 2 shows the MAPE of various data profiles using ANN, GA and PSO. It is found that optimization technique, i.e., PSO has minimum error with better forecasted accuracy.

VI. CONCLUSION

In this manuscript short-term electric forecasting models for (i) hydro generation (million units) power plant, (ii) energy met (million units), and (iii) peak demand (mega watt) of India, are developed using ANN. Additionally, ANN weights are optimized using nature inspired GA and PSO techniques to further reducing the forecasting error as reflected in Table-2. It is found that accuracy obtained from proposed forecasting models is improved by these optimized techniques. Further, PSO methodology shows its superiority over GA methodology. Both the techniques outperforms conventional ANN based model when it is trained using back propagation algorithm.

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