International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 18 (2017) pp. 7202-7206

A Review of Soft Computing Techniques in Short-Term Load Forecasting

Senthil Kumar P

School of Information Technology & Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India.

Orcid Id: 0000-0002-8698-2310

Abstract

Load forecasting plays a significant role in power systems and smart buildings in efficient planning, distribution and management of power. Various exogenous and meteorological factors, gave made accurate load forecasting complex making it a challenging task. In recent years, the research on short-term power load forecasting has become inevitable for the reliable and efficient functioning of power systems. This paper discusses different soft computing techniques such as neural network, fuzzy logic and genetic algorithms for the short term load forecasting.

Keywords: Load Forecasting, Neural Network, Fuzzy logic, Genetic algorithm, soft computing

INTRODUCTION

Load forecasting is an essential task for the successful functioning of any power system. It is very useful for taking decision on power systems such as producing or purchasing of power, planning of energy framework, security. Operational choices in control frameworks, for example, help commitment decision and load demand analysis. Accordingly, accurate load determining encourages electric utility to take up these operations. [1]. Accurate load forecasts helps considerable reduction in the operation and maintenance expenditure, improvement in the power supply system and infrastructure development. Load forecasting is measured through accrual of the power consumption. Effective forecasting of power demand can be made using the power consumption data in the hourly, daily, weekly, monthly and yearly basis.

Forecasting is the assessment of the value of features as could be seen at a future specific point of time. The fundamental point of energy organizations is to give clients an adequate and solid power supply. Production of power, its transmission and distribution is expensive and too valuable permit. On the other hand, load demand is never steady all the times. Many reasons such as changes in climate parameters, limited storage capacity and absence of maintenance cause changes in load demand. Moreover, the growth in the number of customers cannot be anticipated exactly. [2]

Load forecasting can be categorized into three broad groups, namely, short-term, medium-term and long-term. Short-term for load forecasting considers the power consumption data from one hour to one week and is utilized mainly for planning the power generation and transmission. Medium forecasts consider details of a week to a year are utilized to mainly for scheduling fuel purchase. Long-term forecasting considers the consumption of data relating to more than one year and are utilized for building up the power supply and distribution system.

Load forecasting methods mainly use statistical methods or soft computing approaches such as regression, ARIMA, neural networks, genetic algorithm, fuzzy logic, and hybrid expert systems. The accuracy of load forecasting can be improved through use of suitable scientific tools. The performance of load forecasting depends mainly on the load forecasting methods and also on the accuracy of forecast climate situations. Some factors to be considered in short term load forecasting are time factors (time of the year, the day of the week, and the hour of the day), weather data (temperature, humidity etc.,), and possible categories of customers. The medium- and long-term forecasts consider the past load and weather data, the number of customers in different levels or categories (residential, commercial and industry), the utilizations in the particular area, customer age, the economic status, appliance sales data, and other factors [3].

SOFT COMPUTING TECHNIQUES FOR SHORT TERM LOAD FORECASTING METHODS

Professor Lotfi Zadeh introduced the term soft computing with the objective of exploiting the tolerance for imprecision, uncertainty and partial truth to achieve traceability, robustness, low solution cost and better rapport with reality. Soft computing has interrelationship with many fields such as neural networks, genetic algorithm and fuzzy systems. Neural network is important considering its ability to adapt and learn. Fuzzy logic is useful for its exploration of partial truth and imprecision and Genetic algorithm for their application to optimization. The field of probabilistic reasoning is also sometimes included under the soft computing umbrella for its control of randomness and uncertainty. Many statistical and soft computing techniques have been developed for successful short term forecasting. These include similar day approach, regression, time series model, artificial neural networks, expert systems, fuzzy logic and hybrid systems.

The similar –day approaches consider data relating to the past two years and scan the comparable attributes of the forecast on a day to day basis. The factors like day of the week,

weather etc., are considered as the similar characteristics and the load value of the related day is considered as the forecast value.

A. Artificial neural network (ANN)

ANN is described through an information processing model that gets inspiration from the nervous system. The fundamental motivation behind the ANN system examination is the development of a tool that should perform computation for demonstrating the brain. This tool should carry out various computations at a rate faster what is possible from conventional framework. ANN performs various multiple tasks. Some of them are classification, prediction, optimization, identification, evaluation and control of complex systems. The structure of ANN network resembles that of the neuron in the brain. The structure of neural network includes a large number of interconnected processing elements (nodes). Neuron interconnection architecture are of various types, namely single or multilayer feed-forward network, multilayer recurrent network, a single node with its feedback and single-layer recurrent network [17].

During the learning process, known patterns of a particular problem are presented to the network for improving its performance and its ability to generalize. The generalization capability is the ability to respond correctly to the pattern which was not used during the training process. An optimization function method based on gradient descent is applied to reduce the error or maximize the accuracy of the neural network. The learning process is categorized into supervised learning and unsupervised learning. In the supervised learning system, the class label of the pattern presented to the network is known, and it is used in the training process. If the class label is unknown or unused, the learning process is unsupervised.

The basic structure of the ANN consists of three basic layers, namely, input layer, hidden layer and output layer. Each connection link is associated with weight which has information relating to the input signal. The general structure of the ANN is shown in figure 1.

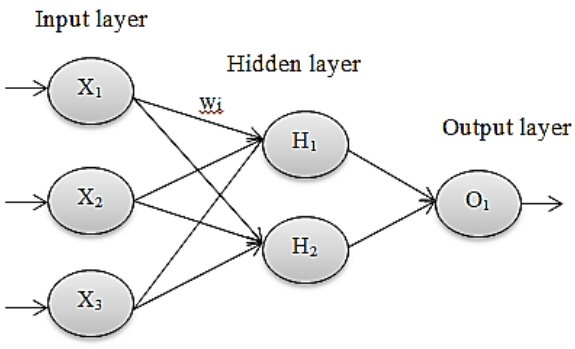

Figure 1: Structure of ANN

The input layer is the layer which transmits the input information of the incoming pattern passed on to the one or more hidden layers. This layer contains a number of input nodes corresponding to the input parameters related to the problem. The identify transfer function is employed to the neuron of this layer. The hidden layers do the work of processing the information coming from the input layer. The sigmoid function activates the neurons of these layers. The number of units depends on the problem. The output layer is the layer which processes the information provided by the last hidden layer. This layer provides the final output of the process by applying the sigmoid transfer unit to each neuron of the layer. The total number of units used in the output layer is related to the number of output parameters of the problem. The ANN may uses several activation functions such as identification of the function, binary step, bipolar step, sigmoid, and ramp function. The binary sigmoid activation function is shown in equation

$$f(x) = \frac{1}{1 + e^{-\lambda x}}$$

The processing units of the ANN learn and generalize the given input load data by adjusting the connection weights and producing the useful decision as output.

Xia et al., [4] have developed a hybrid model for forecasting the electric power load data. The electric power load data is non-linear in nature The Support Vector Machine learning method and the Neural Network soft computing methods were utilized. In this hybrid model, the learning capability and also the prediction accuracy were also improved through the introduction the wavelet analysis along with the artificial intelligence machine learning technique. First, the wavelet analysis was applied. It decomposes the original historical power load data into high frequency load sequences and also low frequency load sequences. Then, the support vector machine and neural network methods were applied for selecting the significant parameters like, penalty parameters, network structures, etc. Then an optimization program did the selection of the kernel function width while the prediction was done separately for each sequence. Following this, the results of each prediction sequences were reconstructed. The final result showed achievement of high forecasting accuracy for the support vector machine technique.

Raza et al., [5] have designed a novel prediction model for electric power load data. The model used artificial neural network and the Global Particle Swarm Optimization technique (GPSO) for efficient short term power load forecasting. ANN was utilized for prediction of the short term load demand on hourly basis for different seasons of a year while the GPSO was utilized to improve the prediction accuracy. The network training was improved by defining the weight bias and the fitness function. The input provided to the feed forward artificial neural network was a correlated lagged load data along with meteorological variables and

exogenous variables. The artificial neural network learnt and predicted the load data needed for the next hour. During the learning process, the weight and bias values were updated by introducing GPSO. With the introduction of GPSO, the accuracy of the artificial neural network should considerable improvement. The showed the achievement of high prediction accuracy by result the artificial neural network with the global particle swarm optimization model and also low convergence time compared to back-propagation technique and a higher generalization capability. Khwaja et al., [6] have proposed an efficient artificial neural network technique for short term power load forecasting. The new technique utilized for the prediction of short term electric power load was Boosted Neural Network (BooNN) which has the ability to reduce computation time, prediction error and variation. It performs the learning process in multiple iterations and, at each iteration, it reduces the error between the output of the previous iteration and the target output. Then the weighted sum of each trained model is estimated and the final prediction output is obtained. As a result, the Boosted Neural Network technique reduces computational time and provides improved prediction accuracy compared to other neural network technique such as, bagged artificial neural network, single artificial neural network, bagged regression trees, ARMA and wavelet neural network. Chaturvedi et al., [7] have suggested a neuron–wavelet method for short-term electric power load forecasting. The combination of wavelet transform and soft computing techniques was utilized for forecasting. Initially, wavelet transform was applied on the original datasets to decompose into fine and course components. Then these components were used as inputs for the soft computing approaches that use generalized neural network (GNN) methods. The GNN was applied separately to each component and finally the outputs of all the components were aggregated to form the final forecasting output. This modified GNN methods achieved high accuracy compared to the other traditional methods. Khwaja et al., [8] have presented Bagged Neural Network (BNN) for short-term load forecasting. The BNN has constructed multiple set of bags from the original load datasets through randomly sampling with a replacement policy, and then applied neural network training on each sampled bag of data, followed by averaging of the outputs of the trained neural networks. The BNN process achieved better reduction in the estimation of error and variation than a single layer neural network for power load forecasting. Dudek [9] has discussed multiple univariate approaches that depend on neural networks for short-term load forecasting. Neural network based univariate approaches include multilayer perceptron, generalized neural network, radial base function neural network, self-organizing maps and fuzzy counter propagation which were discussed and their characteristics were compared. These methods follow a common feature of learning from pattern obtained from seasonal cycle of load time series data. The chronological seasonal variations greater than a day time period were filtered out and used as input for the learning network. This simplified the short-term load forecasting problems. The simulation results of the neural networks were compared with those of Autoregressive Integrated Moving average (ARIMA) and the exponential smoothing method. The generalized regression neural network helped achievement of better results for short-term load forecasting.

B. Fuzzy logic

Fuzzy logic is a mathematical tool which is introduced by lotfiA.Zadehh . It effectively deals the datasets that have uncertainty. It also has the ability to handle information and imprecision granularity. It offers reasoning capability to human beings by using an interference structure. It follows the cognitive process function which is based on the concepts of the relative grading of membership function. It takes uncertain data as input and provides the right decision as output. The membership function provides the results between 0.0 and 1.0. The value 0 represents not belonging to and the value 1 represents belonging to. The values in between 0 and 1 represent fuzziness. The inference engine of the fuzzy logic performs approximate reasoning comparable to the human brain. The fuzzy inference engine is made of collection of linguistic rules. The non-linear mathematical representation can be used for writing a fuzzy system which supports the non-linear mapping from the input data to output decisions. Thus, the fuzzy system provides an efficient solution for many of the complex problems.

Bakirtzis et al., [10] have developed a fuzzy system by creating rule base from the historical power load datasets. This fuzzy system consists of a network structure and a learning process as the neural network. This network is known as fuzzy network. Initially, this system constructs the rule base from the available historical electric power load data. Then, the training process is applied on the constructed rule base to tune its parameters. The results of the fuzzy neural networks map the historical data sufficiently. After training the fuzzy network structure, can be used to predict the future load. The result shows that the processing speed of the fuzzy network structure as faster compared to neural network and also its achievement high accuracy compare to neural network. Sachdeva and Verma [11] have designed a new load forecasting method that consists of a combination of the ANN and fuzzy logic. This approach was seen effectively forecasting the electric power load on a daily basis. The past power load data records from an engineering college was utilized as dataset while the mamdani type fuzzy membership function was used for the analysis. In addition to this, the fuzzy system was processed along with the ANN with reduced number of iterations. A dramatic reduction in the error of load forecasting with the range of 2-3% was seen. Hsu et al., [12] have developed an expert system for short-term load forecasting using fuzzy logic. It has utilized Taiwan power system data for analysis. The fuzzy system takes this power data as input and deals with the uncertainties found in weather

data. The results show that a fuzzy system achieves an improved accuracy for hourly based short-term load forecasting. Srinivas and Jain [13] have presented a new methodology for short-term load forecasting. The methodology has used the fuzzy logic concept that considers the impact of temperature and humidity of the load data. A load curve of the similar day was utilized for getting the forecast of day load curve. The similar day was identified by using a new Euclidian distance calculation with weight factors. The correction factors of the similar days were calculated by using either previous similar day or previous day information for forecasting the required day. The results showed achievement of improved accuracy with 3% of Mean Absolute Percentage Error (MAPE) by the proposed methodology. Pandian et al., [14] have utilized the fuzzy logic system for load forecasting. The fuzzy systems consider time and temperature of the day as input and produce the forecasted load as the output. The time and temperature were decomposed into eight and four triangular membership functions respectively. The output forecasted load was decomposed into eight triangular fuzzy membership functions. The relationship between the input and output of the problem was defined by fuzzy rule techniques using linguistic terms. Finally, the forecasted values obtained from fuzzy system were compared with output of the traditional forecasting method. The tested results show that the forecasted load accuracy matches with the actual load curve with 3%.

C. Genetic algorithms

Genetic algorithm is developed on the basis of the functioning of genetics systems. It is a computational procedure executed repeatedly on a set of population with operators such as selection, crossover and mutation. It moves form one iteration to iteration by using the objective function and also probabilistic transition rules alone. This algorithm cannot operate on the parameters as it is, it can operate only on the codded version of the parameters. Genetic algorithm uses set of population solutions where each solution is described by chromosomes. First the selection process is done on the basis of the probability of the fitness of the individual. the best ones are selected this way . In the reproduction stage, the selected ones are used for the generation of new chromosomes. The algorithm utilizes the mutation and recombination for the generation of new chromosomes. Then fitness of the generated new chromosomes is calculated. Finally, the new chromosomes replace the old ones and the algorithm is stopped when the population reaches optimal solution. The flowchart of a Genetic algorithm is shown in figure 2.

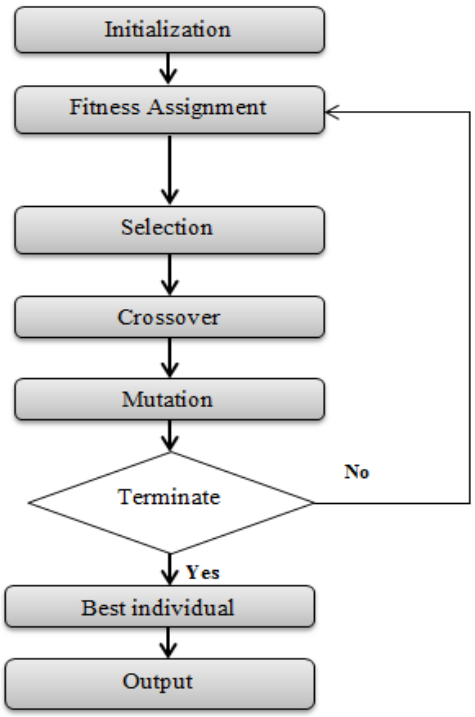

Figure 2: Flowchart for Genetic algorithm

Gupta et al., [15] have proposed a powerful tool for the power load forecasting using Genetic Algorithm BackPropagation Network (GA-BPN). The best weights of different layers backpropagation network are effectively extracted using a GA-BPN model. This helps predicting the accurate future power load. The results show the introduction of the connection weight helps for the accurate power prediction. Heng et al., [16] have developed a model which is a combination of genetic algorithm and neural network for short-term forecasting. The neural network model was trained using a genetic algorithm. The evolution method has been used for optimization problems. In the proposed model, the ANN techniques uses 3-layered feedforward back propagation network. The results show that the proposed combined model achieves better accuracy than other conventional statistical models.

CONCLUSION

Load forecasting is an important task for decision making and the energy markets. Now-a day, the efficient power system operation depends mainly on the accurate forecasting of electric power data. This paper deals with the different techniques employed for accurate short term load forecasting in recent years. The neural network techniques and the combination of neural network and other techniques such as neuron-Wavelet, Back-propagation Neural Network, Neural Network with Support Vector Machine, Neural Network with

Particle Swarm Optimization, Boosted Neural Network have been utilized for load forecasting and their results have been discussed. The fuzzy logic and genetics algorithm functioning and their contribution in the forecasting of power load data have also been discussed. Finally, the review concludes that the forecasting based on the soft computing technique can provide an accurate forecasting result with less computational time and error for the complex non-linear time series datasets.

REFERENCES

[1] Feinberg, E. A., & Genethliou, D. (2005). Load forecasting. Applied mathematics for restructured electric power systems, 269-285.

[2] Ali, D., Yohanna, M., Puwu, M. I., & Garkida, B. M. (2016). Long-term load forecast modelling using a fuzzy logic approach. Pacific Science Review A: Natural Science and Engineering, 18(2), 123-127.

[3] Srivastava, A. K., Pandey, A. S., & Singh, D. (2016). Short-term load forecasting methods: A review. In Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES), International Conference on (pp. 130-138). IEEE.

[4] Xia, C., Zhang, M., & Cao, J. (2017). A hybrid application of soft computing methods with wavelet SVM and neural network to electric power load forecasting. Journal of Electrical Systems and Information Technology.

[5] Raza, M. Q., Nadarajah, M., Hung, D. Q., & Baharudin, Z. (2017). An intelligent hybrid short-term load forecasting model for smart power grids. Sustainable Cities and Society, 31, 264-275.

[6] Khwaja, A. S., Zhang, X., Anpalagan, A., & Venkatesh, B. (2017). Boosted neural networks for improved short-term electric load forecasting. Electric Power Systems Research, 143, 431-437.

[7] Chaturvedi, D. K., Premdayal, S. A., & Chandiok, A. (2010). Short-term load forecasting using soft computing techniques. International Journal of Communications, Network and System Sciences, 3(03), 273.

[8] Khwaja, A. S., Naeem, M., Anpalagan, A., Venetsanopoulos, A., & Venkatesh, B. (2015). Improved short-term load forecasting using bagged neural networks. Electric Power Systems Research, 125, 109-115.

[9] Dudek, G. (2016). Neural networks for pattern-based short-term load forecasting: A comparative study. Neurocomputing, 205, 64-74.

[10] Bakirtzis, A. G., Theocharis, J. B., Kiartzis, S. J., & Satsios, K. J. (1995). Short term load forecasting using fuzzy neural networks. IEEE Transactions on Power Systems, 10(3), 1518-1524.

[11] Sachdeva, S., & Verma, C. M. (2008, October). Load forecasting using fuzzy methods. In Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008. Joint International Conference on (pp. 1-4). IEEE.

[12] Hsu, Y. Y., & Ho, K. L. (1992, November). Fuzzy expert systems: an application to short-term load forecasting. In IEE Proceedings C (Generation, Transmission and Distribution) (Vol. 139, No. 6, pp. 471-477). IET Digital Library.

[13] Srinivas, E., & Jain, A. (2009, March). A methodology for short term load forecasting using fuzzy logic and similarity. In The Nat. Conf. on Advances in Computational Intelligence Applications in Power, Control, Signal Processing and Telecommunications.

[14] Pandian, S. C., Duraiswamy, K., Rajan, C. C. A., & Kanagaraj, N. (2006). Fuzzy approach for short term load forecasting. Electric Power Systems Research, 76(6), 541-548.

[15] Gupta, A., & Sarangi, P. K. (2012). Electrical load forecasting using genetic algorithm based back-propagation method. ARPN Journal of Engineering and Applied Sciences, 7(8), 1017-1020.

[16] Heng, E. T. H., Srinivasan, D., & Liew, A. C. (1998, March). Short term load forecasting using genetic algorithm and neural networks. In Energy Management and Power Delivery, 1998. Proceedings of EMPD'98. 1998 International Conference on (Vol. 2, pp. 576-581). IEEE.

[17] Sivanandam, S. N., & Deepa, S. N. (2007). Principles of Soft Computing, John Wiley & Sons.