Intelligent Energy Consumption Prediction Systems using Machine Learning Algorithms

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Abstract

The exorbitant rise in demand of electricity due to rapid growth of global population coupled with large scale industrial revolution have consequently led to Global energy crisis. In such a scenario, efficient use of electric power assumes significance. Researchers in the past decade have focussed attention towards developing efficient electric energy consumption forecasting systems which through accurate forecasting can immensely aid in efficient scheduling, load flow management and analysis, contingency analysis as well as in efficient planning and maintenance of the electric power supply systems. Machine learning algorithms have proved to be quite efficient in forecasting short term as well as long term electric load demand. This paper reviews the recent research in the field of developing efficient machine learning based energy consumption forecasting systems.

Keywords: Electric load forecasting, Energy consumption, Machine learning, Prediction Systems.

I. Introduction

Energy Consumption Prediction systems can aid in cutting the energy demand curve and ultimately aid in better power management. Such systems require accurate prior knowledge of the electric energy demand patterns. However, energy consumption depends upon a number of factors like climate change, time periods and other factors like economic health and the power policies of the government etc. Precise and consistent prediction techniques can help raise reliability of power systems and improve the functionality of electric load management systems to be able to cater to the energy demand of the consumers and the energy utilities.

Regression analysis approaches were initially used to predict the energy consumption levels by the consumers **(Charytoniuk, W. et al, 1998)**. However, it is hard to determine the energy demand patterns using the conventional statistical methods using historical load data. Energy patterns are governed by a number of other factors which are hard to determine using the conventional statistical techniques **(Momoh, J., et al, 1995).**

To develop precise energy consumption forecasting models, non-linear techniques need to be employed to be able to capture the non-linear and complex data related to the factors that affect the energy demand.

Machine learning algorithms being self-adaptive, of late have been quite successful in capturing the non-linear data as well as the complex relationships between the variables. This paper reviews some of the latest research work in the area of application of different machine learning algorithms to build intelligent, self-learning energy consumption prediction systems that have contributed significantly towards better management of real-world energy systems.

II. Literature Survey

Ili´c, S. et al (2013) used ANNs for short term load forecasting for large scale systems. The model proposed by them comprised of two units arranged in sequence. The first unit comprised of a pre-processing unit used for data preparation which was then fed as input to the second unit comprising of ANN unit. The ANN was then used for forecasting hourly electricity load requirements. The Pre-processing unit considerably helped in reducing the dimension of the input data which further aided in faster training of the ANN due to reduced number of training parameters to be set for training the ANN. All this also led to improvement in the generalization capability of the ANN. Two models using the system were proposed. The first one comprised of single ANN with 24 outputs while the second model comprised of 24 separate ANNs and a single output. The first model provided better forecasting results. This model could be used for online training and adaptation which is quite essential for large scale energy systems.

Rodrigues et al (2014) used ANN to forecast daily as well as hourly electricity consumption of households.Daily energy consumption of 93 households in Lisbon and Portugal during the period between February 2000 and July of 2001 was used for training the ANN. The study used feed forward ANN which was trained using the Lavenberg-Marquardt training algorithm. The ANN architecture used for daily maximum, daily average and hourly energy consumption forecast comprised of twenty neurons in the hidden layer and one neuron in the output layer. R^2 value of 96.6% was achieved for the first day daily forecast while a R^2 value of 97.9% was achieved for third day daily forecast.

Chou and Bui (2014) used AI techniques for estimating energy performance of the buildings. The techniques used by them included ANNs, Support Vector Regression, Regression tree, Chi-squared automated detector, General Regression model and ensemble reference technique. Data from 768 experimental datasets were used for constructing the forecasting models. The models used 8 parameters for input while for output the parameters used were heating load and the cooling load. The ensemble model of SVR+ANN proved to be the best model for forecasting the Cooling load while the SVR model provided best forecasting estimates for the Heating Load.Both these models obtained MAPE values below 4% and these models showed considerable accuracy compared to the earlier works for forecasting the heating and cooling loads. These models were proposed for early building designs for constructing energy efficient buildings.

Bianchi et al. (2015) employed echo state networks, a type of Recurrent Neural Networks along with PCA decomposition to propose a novel method for improving the prediction accuracy of Short term Load forecasting problems. For this study, they considered time series data comprising of electric load measurements of power grid located in Rome. They considered two cases for the study, the first being the one with leading time equal to 1 while the second case considered for the study had a leading time of 144. For improving the forecasting accuracy in the second case, the time series data of daily electric load measurements sampled every 10 minutes is arranged in the form of a matrix. Then the m step ahead forecasting problem comprises of forecasting the values of row t+1, if given the values of t^{th} row of the matrix. The authors proposed retrieving the first k principal components from the matrix using the PCA decomposition method. The components being orthogonal can be independently forecasted using k discrete parameters .The problem of m-steps ahead forecasting can then be reduced to k number of 1-step ahead forecasting tasks. The solutions are then combined to give the final result. The forecasting model proposed in the study utilized k separate echo state networks, on each for every principal component selected. The Genetic Algorithm was used to determine the optimal parameters.

The proposed method was tested for forecasting the electricity load in fifty days. Two cases with different leading times-10 minutes and one day were considered. The results were compared with the ARIMA method. The proposed method demonstrated considerable accuracy over the results obtained through ARIMA method.

Protic et al. (2015) developed forecasting models for direct heating systems using a hybrid of Support Vector Machines and Wavelet Transform method. Data from direct heating systems during the heating season of the time period 2009 to 2010 was used for the study. Using different forecasting time horizons ranging between 1 hour and 24 hours ahead, nine forecasting models were created using the hybrid of SVM and Wavelet Transform. The results were compared with the Genetic Programming method and those obtained using the ANN method. Results obtained better prediction accuracy for the hybrid SVM-Wavelet Transform model over the Genetic Programming and the ANN models.

Chitsaz et al(2015), in their study proposed a method for forecasting the electric load of a micro grid, the load time series of which is characterized byhigh volatility. They proposed Self Recurrent Wavelet Neural Network as the forecasting model. The model was tested on forecasting the electric load of a micro grid associated education building. Laven Marquardt algorithm was employed as the training algorithm.On comparison with the other models, the proposed model was found to be quite efficient.

Deb et al (2016) in their study proposed a forecasting model based on ANN to predict the diurnal energy consumption of buildings of educational institutes.Detailed analysis of two years of energy consumption data of these buildings revealed high variability in the data. The data was hence divided by the authors into classes and the class numbers were taken as input for the ANN.The feed forward ANN trained using the Bayesian regularization algorithm was found to be the most efficient model for forecasting the energy consumption of the cases under study. The model was able to predict for a time horizon of up to 21 days with the R2 values declining to 0.9694 from 0.9852.

Idowu et al. (2016) used machine learning algorithms, namely,Support Vector Machines, Artificial Neural Networks, Regression trees and Multiple linear regression to propose a suitable prediction model for forecasting the thermal load of heating substations. They used the load data of ten buildings which included five residential buildings and an equal number of commercial buildings, located in Sweden. The input parameters considered for the study included outdoor temperature, historical thermal load data, physical attributes of the thermal substations and the time factor variables. Time horizon ranging from 1 hour upto 48 hours was considered for prediction purposes. The results revealed maximum prediction accuracy for Support Vector Machines while minimum accuracy was reported for the Regression Tree model.

Chen Y. et al. (2017) predicted one day ahead hourly demand of electric power using a hybrid model of Support Vector Regression model and Multi Resolution Wavelet Decomposition Model. They used a training sample comprising fifteen parameters for 29 days. For a typical day, the relative Error obtained was 5.6% but this model worked only for ε (ε-non-insensitive loss function) values higher than 0.1.

Kaboli S. H. A., et al (2017), in their study used optimised gene expression programming to forecast long term electric energy consumption. They used historical data from ASEAN-5 countries to forecast electric power consumption up to 2030. The Optimised gene expression programming is an extension of Gene expression Programming, with a high probability of reaching a closed form solution without prior knowledge about the relationships between the different input variables. They compared the proposed method with other AI based algorithms like Artificial neural Networks, ANN (artificial neural network), SVR (support vector regression), ANFIS (adaptive neuro-fuzzy inference system), rule-based data mining algorithm, GEP, linear and quadratic models optimized by PSO (particle swarm optimization), CSA (cuckoo search algorithm) and BSA (backtracking search algorithm). The results showed that the proposed method performed better than all the considered AI based methods. The study further predicted the energy consumption till 2030.

Zeng N. et al (2017) used a combination model of extreme learning machines and Switch delayed Particle Swarm Optimisation (SDPSO) Model for Short Term Load Forecasting. The SDPSO model is initially used to optimise the weights and biases of the Extreme Learning Machine Model and then uses delayed information of Local-best and global-best particles to update the velocity of a particle. The tanh function was used as an activation function. This method prevents use of unnecessary hidden nodes as well as overtraining problems. The results obtained were compared with Radial Basis function Neural Network and the proposed model displayed better performance.

Mordjaoui et al (2017) conducted a study to forecast electric load using dynamic Artificial Neural Networks. Back Propagation Method was used for time series prediction. The model proposed by the researchers reported Mean Absolute Percent Error of 3.266% and 4.233% for historical loads. The results obtained proved the efficiency of the proposed model as compared to the conventional forecasting models.

Olajuyin E. A. (2018) used ANN to forecast the electric consumption of Ogun State based Federal University of Agriculture. For the study, he used monthly based data of electricity consumption for the period ranging from 2008 to 2013. He developed an ANN model for forecasting the electric consumption for the university from 2013 to 2027. A correlation coefficient of 0.69 was obtained using the Regression Plots, thereby validating the model for long term electric load consumption forecasting.

Singh, P. and Dwivedi, P. (2018) combined ANN with machine learning algorithms to reduce the prediction error and find optimised neural network parameters. The new model thus developed was based on the follow the leader concept. It was further validated using COCO (Comparing Continuous Optimizers) framework. It was used on a set of twenty four BlackBox Optimization Benchmarking functions. Twelve algorithms in 2-D, 3-D, 5-D, 10-D, and 20-D were used. The proposed model performed best for 20 D while it was ranked second best for all other dimensions. This model was then combined with ANN for finding optimal network parameters and was then tested successfully on electric load data sets of New South Wales, Electric Reliability Council of Texas and New Pool England. The proposed hybrid model was then compared with BPNN and other ANN hybrids of GA, Jaya and PSO. The proposed model outperformed all these models.

Kuo, P. and Huang, C. (2018) developed a deep convolutional neural network called Deep Energy for forecasting electric load using the consumer electric load demand of coastal areas of USA. The proposed prediction model which could forecast three day ahead demand was compared with other AI models, namely Support Vector Machine, Radial Function, Multi-Layer Perceptron, Long Short Term Memory Network and Decision Tree. In all cases the proposed model reported minimum Mean Absolute Percentage Error (MAPE) and Cumulative Variation of Root Mean Square Error (CV-RMSE) which thereby proved its robustness and effectiveness.

Houimli, R. et al (2019) developed an ANN model to predict the half hourly electric energy demand of Tunisia over a period from the year 2000 to year 2008 using the climatic and calendar data along with the historical load values. The researchers compared the ANN model using Levenberg–Marquardt learning algorithm with the ANN models that used conjugate gradient and the Back Propagation algorithms. The results showed that ANN model using Levenberg–Marquardt learning algorithm showed better performance as compared to the ANN models with the other two learning algorithms.

III. Conclusion

Significant research has been conducted in the area of application of machine learning algorithms towards development of efficient prediction systems that can precisely predict the energy demand and hence the consumption of electric energy which have led to development of better power management systems. This assumes significance in the current scenario when the global energy crisis looms large over the world. Research shows that the machine learning based prediction systems can predict the short term as well as the long term electric load consumption more accurately as compared to the systems employing conventional statistical techniques. Further scope of research in this area includes testing hybrid models of various machine learning algorithms as well as the statistical techniques to develop even more efficient intelligent power consumption systems.

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