International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6S3, September 2019

Smart Customer Demand Forecast with Substantial Energy Demand Variability

Padala Navya Meghana, Ponnam V. Kishore Babu, K Swarna Sri

Abstract:- ***Load forecasting in an emerging smart grid has become a challenging task. This paper presents an innovative approach to forecast highly variable smart customer load using smart meter energy consumption data. The smart meter data is systematically linearized by applying extended k-means clustering approach, smoothing the linearized load profiles and then linearizing the load profiles using Taylor series linearization process. Case studies are presented using real world smart meter data and then applying the proposed approach and artificial neural network. Four different scenarios are considered for forecasting and the results showed that, in case of high variability in smart customer energy demand, the accuracy of forecasting using linearized profiles is higher than using original non-linear profiles as the source of forecasting. The forecasting process was repeated several times to verify the robustness of the approach and the results justify the accuracy of the forecast further with the proposed approach.***

I. INTRODUCTION

Efficient and reliable transmission and distribution of electricity is a fundamental requirement for providing societies and economies with essential energy resources[1]. The utilities in the industrialized countries are today in a period of change and agitation. On one hand, large parts of the power grid infrastructure are reaching their designed end of life time, since a large portion of the equipment was installed in the 1960s [2]. On the other hand, there is a strong political and regulatory push for more competition and lower energy prices, more energy efficiency and an increased use of renewable energy like solar, wind, biomasses and water. In industrialized countries, the load demand has decreased or remained constant in the previous decade, whereas developing countries have shown a rapidly increasing load demand

Aging equipment, dispersed generation as well as load increase might lead to highly utilized equipment during peak load conditions. If the upgrade of the power grid should be reduced to a minimum, new ways of operating power systems need to be found and established. In many countries, regulators and liberalization are forcing utilities to reduce costs for the transmission and distribution of electrical energy. Therefore, new methods (mainly based on the efforts of modern information and communication techniques) to operate power systems are required to guarantee a sustainable, secure and competitive energy supply.

The general goals of Smart Grid [3] are to ensure a transparent, sustainable and environmental-friendly system operation that is **cost and energy efficient, secure and safe**. Objectives of developing the Smart Grid are quite different from country to country for their various demands and start points. However, the common objectives of a Smart Grid are clear and listed below:

- *Robustness*: The Smart Grid shall improve resilience to disruption to provide continuous and stable electricity flows, avoiding wide-area breakout accidents. It shall guarantee the normal and secure run of the electricity grid even under the instance of emergency issues, such as natural disasters, extreme weather and man-made breakage, and provides self-healing abilities[4];
- *Secured operation*: The Smart Grid shall enhance communication networks and information security of the electricity grid;
- *Compatibility*: The Smart Grid shall support the integration of renewable electricity such as solar and wind, has the capacity of distributed generation access and micro-grids, improve demand response functions, implement the effective
- two-way communication with consumers and satisfy various electricity demands of consumers
- *Economical energy usage*: The Smart Grid shall have the capacity of more effective electricity markets and electricity trades, implement optimized configuration of resources, increase efficiency of the electricity grid, and reduce electricity grid wastage;
- *Integrated system*: The Smart Grid shall highly integrate and share information and data of an electricity grid, utilize the uniform platform and model to provide standardized and refined management;
- *Optimization*: The Smart Grid shall optimize assets, reduce costs and operate efficiently;
- *Green energy*: The Smart Grid shall solve problems of energy security, energy saving, carbon dioxide emission and etc.

Manuscript published on 30 September 2019.
***** Correspondence Author (s)
Padala Navya Meghana, PG Scholar, Department of EEE, R V R & J C College of Engineering, Guntur, Andhra Pradesh, India.
Ponnam V. Kishore Babu, Asst. Professor, Department of EEE, R V R & J C College of Engineering, Guntur, Andhra Pradesh, India.
K Swarna Sri, Professor, Department of EEE, R V R & J C College of Engineering, Guntur, Andhra Pradesh, India.

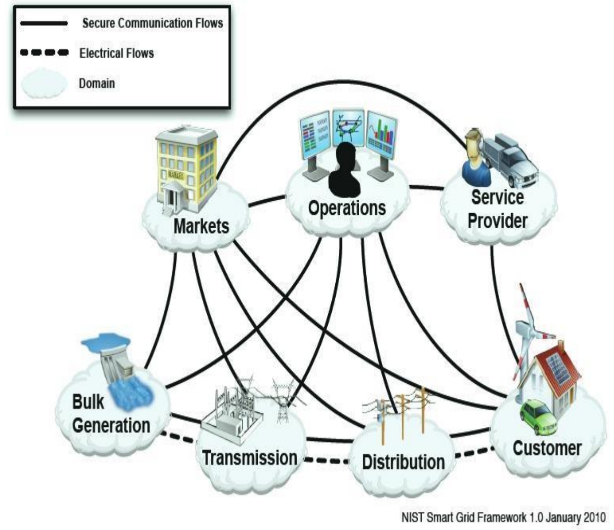


Figure 1. A conceptual model of Smart Grid Smart Grid has the following fundamental characteristics:

- Use of information, computing, networking technologies to support the envisioned Smart Grid services: energy distribution management, energy trading, grid monitoring and management, distributed renewable energy integration, electric vehicles charging, distributed energy storage, and smart metering infrastructure;
- The Smart Grid services involve many parties across many domains, in particular active participation of customers is essential;
- Smart Grid requires new capabilities in each functional plane to achieve its goal of energy efficiency, reliability, and automation, such as new algorithms in the Services/Applications plane, security and QoS-awared two-way communications in the Communication plane, two-way transmission capability, storage techniques, and new intelligent sensors/controllers in the Energy plane;
- In order to support these services, the ICT systems must
  - provide wide range of applications such as home, building, and factory energy management systems, on demand meter readings, demand and response systems, electrical grid status monitoring, fault detection, isolation, and recovery;
  - manage wide variety of devices such as intelligent sensors, smart meters, smart appliances, and electric vehicles;
- The network infrastructure must provide reliable two- way communication and support various class of QoS, such as real-time and non-real-time, and different bandwidths and latency, loss, and security requirements;
- To ensure the interoperability of applications and devices, interoperable standards are required for communications, information representations and exchanges; Security of services, applications, devices in all domains, including the networks are of paramount importance to the stability and integrity of the Smart Grid.

II. LITERATURE SURVEY

The electric matrix conveys power from purposes of age to shoppers, and the power conveyance system capacities by means of two essential frameworks: the transmission framework and the dispersion framework. The transmission framework conveys power from power plants to circulation substations, while the dispersion framework conveys power from appropriation substations to buyers. The framework likewise includes hordes of neighbourhood that utilization appropriated vitality assets to serve nearby loads as well as to meet explicit application prerequisites for remote power, town or locale control, premium power, and basic burdens assurance.

Electric framework partners speaking to utilities, innovation suppliers, scientists, policymakers, and customers have cooperated to characterize the elements of a Smart Grid. Through provincial gatherings assembled under the Modern Grid Strategy task of the National Energy Technology Laboratory (NETL), these partners have recognized the accompanying attributes or execution highlights of a Smart Grid:

- Providing power quality for 21st century needs.
- Accommodating all age and capacity choices.
- Enabling new items, administrations, and markets.

"Brilliant Grid" is today utilized as advertising term, as opposed to a specialized definition. Hence there is no very much characterized and usually acknowledged extent of what "shrewd" is and what it isn't. Anyway savvy advancements improve the perceptibility as well as the controllability of the power framework. . In this way Smart Grid advancements help to change over the power framework from a static foundation to be worked as planned, to an adaptable, "living" framework worked proactively. IEC SG3 characterizes Smart Grids as the idea of modernizing the electric framework. The Smart Grid is coordinating the electrical and data advances in the middle of any purpose of age and any purpose of utilization. Models:

- Smart metering could fundamentally improve learning of what's going on in the conveyance network, which these days is worked rather indiscriminately. For the transmission framework, an improvement of the recognisability of framework wide powerful marvels is accomplished by Wide Area Monitoring and System Integrity Protection Schemes.
- HVDC and FACTS improve the controllability of the transmission matrix. Both are actuators, for example to control the power stream. The controllability of the appropriation network is improved by burden control and robotized circulation switches.
- Common to a large portion of the Smart Grid advancements is an expanded utilization of correspondence and IT innovations, including an expanded communication and incorporation of once in the past isolated frameworks.

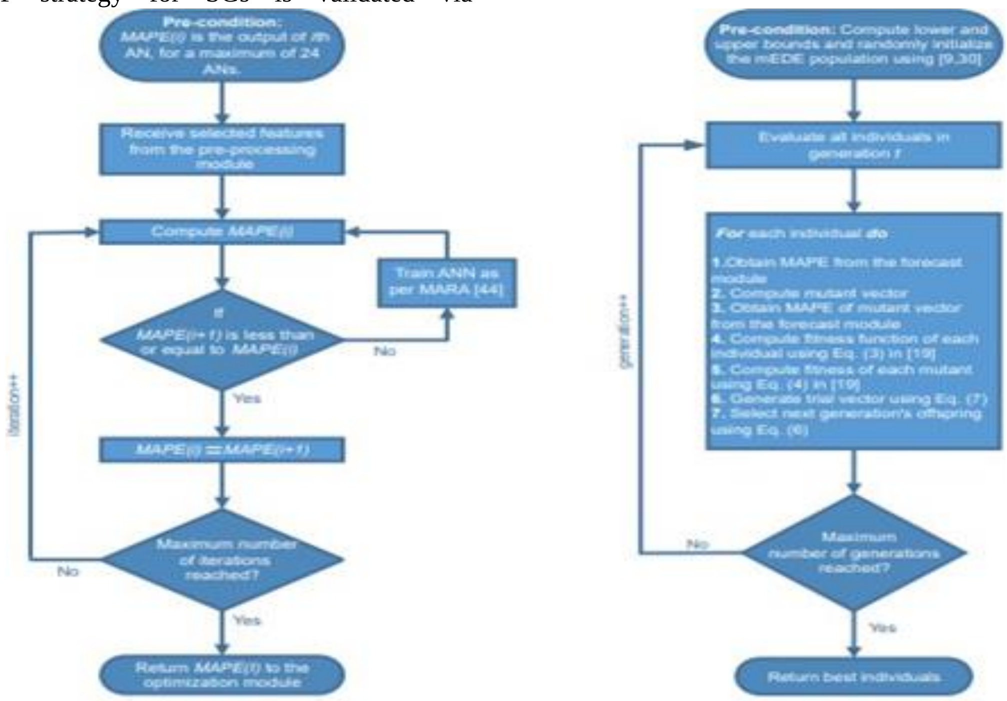
A Smart Grid is a power arrange that can cost proficiently incorporate the conduct and activities of all clients associated with it generators, purchasers and those that do both so as to guarantee monetarily productive ,manageable power framework with low misfortunes and abnormal amounts of value and security of supply and wellbeing.

Retrieval Number: F12360986S319/2019©BEIESP
DOI:10.35940/ijeat.F1236.0986S319
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

III. METHODOLOGY

A case study was simulated using real world smart meter data from NEW ENGLAND ISO for every hourly energy consumption data. In our proposed work, a hybrid ANN-based DALF model for SGs is presented which is a multi-model forecasting ANN with a supervised architecture and [5] MARA for training. The proposed model follows a modular structure (it has three functional modules): a pre-processor, a forecaster, and an optimizer. Given the correlated lagged load data along with influential meteorological and exogenous variables as inputs, the first module removes two types of features from it: (i) redundant; and (ii) irrelevant. Given the selected features, the second module employs ANN to predict future values of load. The AN is activated by sigmoid function and the ANN is trained by MARA. We further minimize the forecast/prediction error by using an optimization module in which a [6] heuristics-based optimization technique is implemented. The proposed DALF strategy for SGs is validated via simulations which show that our proposed strategy forecasts the future load of SGs with approximately 98.76% accuracy. To sum up, this paper has the following contributions/advantages: • The proposed model takes into account external DALF influencing factors such as meteorological and exogenous variables. • Due to better accuracy and less execution time, we have used [7] MARA for training which none of the existing forecast models has used for training. • To improve the forecast accuracy and minimize the execution of the forecast model, we have performed local training which none of the existing forecast models has used. [8]NARXNN architecture creates feedforward back propagation with feedback from output unit to input unit. The first hidden layer receives weight from input unit. Each subsequent layer receives weight from the previous layer. The NARXNN can be carried out in one out of the following two modes: Series-Parallel (SP) Mode and Parallel mode. In SP mode, the output's regression is formed only by the actual values of the system's output



(a) Forecast module (b) Optimization module

Figure 2: Flow Charts for optimization and forecast model using ANN

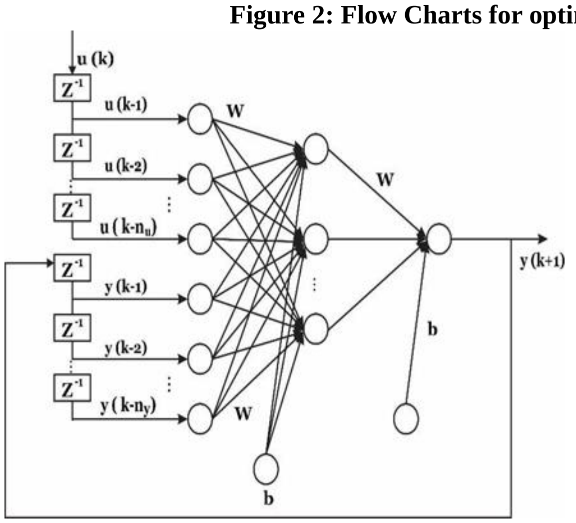


Figure 3. NARX Neural Network

In Parallel (P) Mode, estimated outputs are fed back and included in the output's regression. The P mode NARXNN architecture can be represented in Figure 3.

The dynamics of multi-layer perceptron (MLP) neural network consists of an input vector composed of past values of the NN input and output. This is the approach by which the MLP can be considered as a NARX model of the system. This way of introducing dynamics into a static network has the advantage of being simple to implement. To deduce the dynamic model of realized NN system, NARX P-type NN model [9] can be represented as follows:

$$(k + 1) = fANN = ((k), (k - 1), \dots y(k - n + 1), (k), (k - 1), \dots u(k - m + 1) + \in (k)$$

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

where y(k+1) is model predicted output, fANN is a non-linear function describing the system behaviour, y(k), u(k), ε(k) are output, input and approximation error vectors at the time instances k, n and m the order of y(k)and u(k) respectively. The order of the process can be predicted from experience.Modeling by NN depends on the considerations of an approximate function of fANN. Approximate dynamic model is developed by adjusting a set of connection biases (b) and weight (W) via training function defined as MLP network

Training Functions

Several different training functions are available for feed forward network [11]; some of the training functions in mat lab and their associated training parameter [10, 11] are listed in Table1.

The accuracy of the training function depends on the number of data used in the training set, the number of biases and weights in the network and the error goal, etc.

Tracking Signal

The calculation of the TS [12] is represented in the equation (3). If the forecast value is lower than the actual value then the model is in under forecasting and TS will be positive. If the forecast value is higher than the actual value then the model is in over forecasting and TS will be negative.

Forecasting Performance

The forecasting performance is evaluated using the statistical measures, namely, mean absolute percentage error (MAPE) [13], Mean Absolute Error (MAE), percentage of accuracy (POA). In the following measure ft represents forecasted value and yt represents actual value, $et = yt - ft$ represents forecast error and n represents the size of the test set.

The performance of a forecasting model is evaluated by the MAPE which is used in a measure of prediction accuracy of a forecasting method. It usually expresses accuracy as a percentage, and is defined by the formula

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{e_t}{y_t}X100 \;\ldots\ldots\ldots\ldots (1)s$$

Percentage of Accuracy (POA) [14] is one of the forecast bias measurements. If the ratio of POA is 100 percent, then it indicates the forecast is unbiased. The value of POA is 95 to 110% indicates the better forecast model. The value of POA is closer to 100% indicates the best forecast model

The Mean Absolute error (MAE) [15] measures the It measures the average absolute deviation of forecasted values from original ones

$$MAE = \frac{\sum_{t=1}^{n}|e_t|}{n} \ldots\ldots\ldots (3)$$

IV. RESULTS

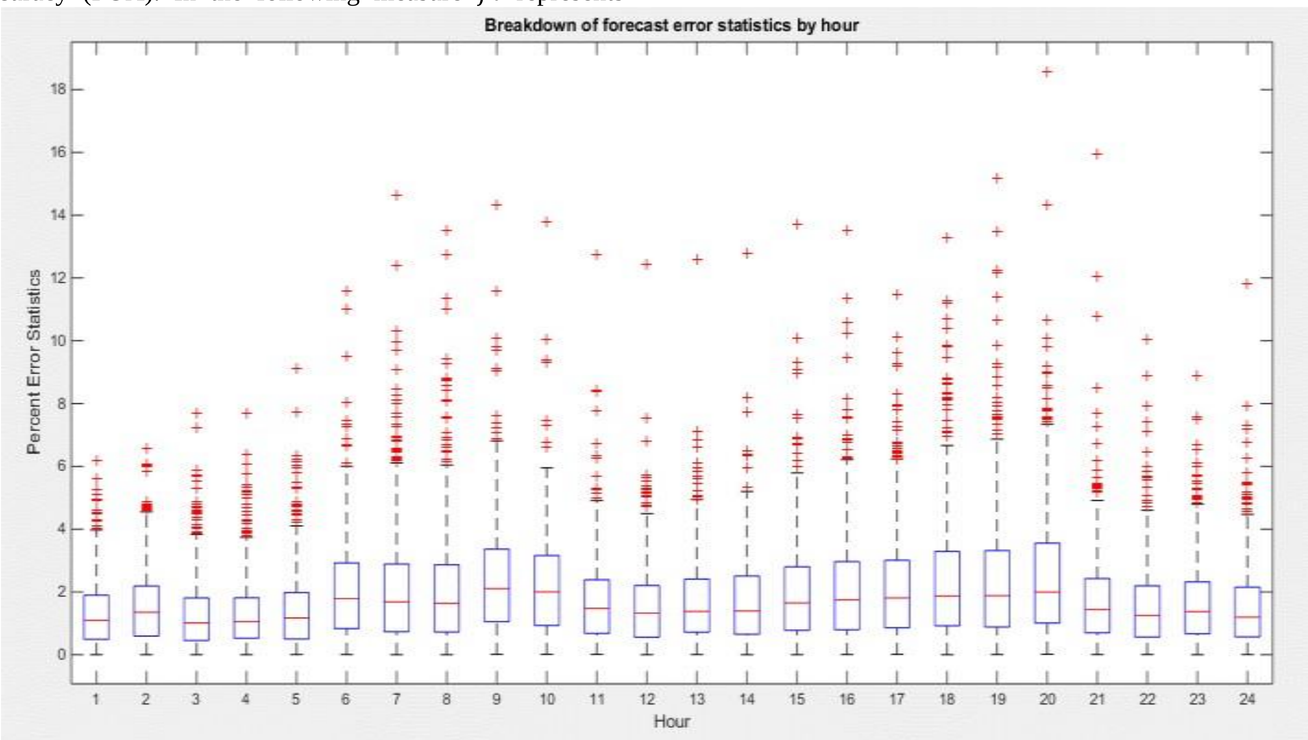


Figure 4: Forecast error for every hour

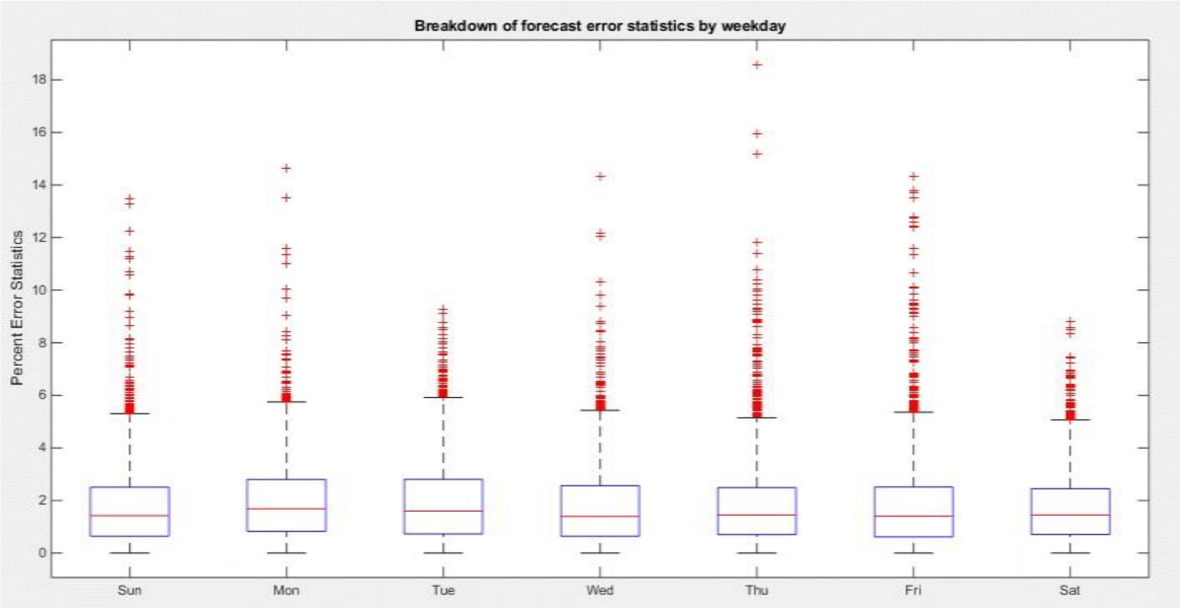


Figure 5: Forecast error for every week

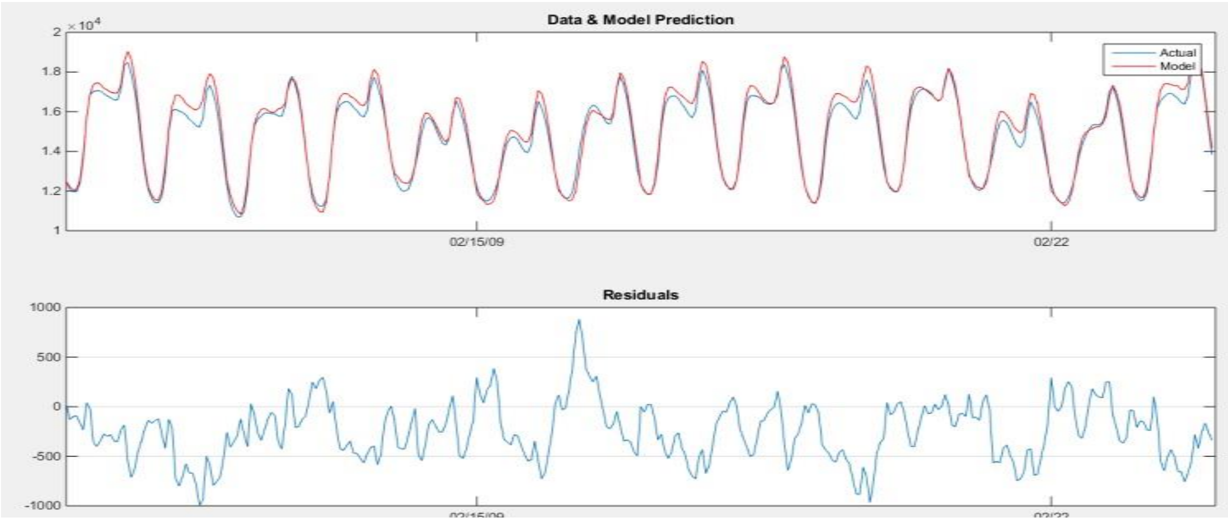


Figure 6: Comparison of actual and prediction values

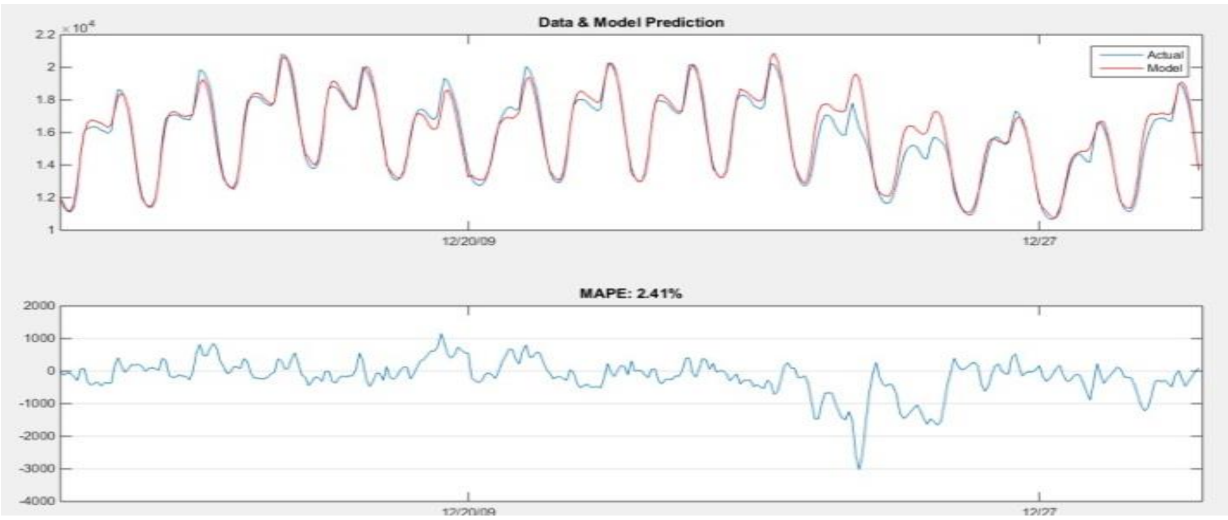


Figure 7: Mean absolute percentage of error

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

V. CONCLUSION

This paper proposed an innovative approach for smart meter customer load forecasting by restructuring the non-linear energy meter profiles into linearized profiles. The robustness of the approach was justified using highly variable smart meter customer demand data.

The case study justified the value of using the proposed approach against the neural networks, in particular with highly variable smart meter customers' demands. The aggregation of the cluster forecast proved to provide a more accurate forecast while preserving the volatility of the data.

Approach can be incorporated into the planning and operation of smart power systems where the active customer participation is highly volatile due to habitual patterns, multitudes of active customer owned business models, and prosumer operation.

REFERENCES

1. Y. Loewenstern, L. Katzir, and D. Shmilovitz, "The effect of system characteristics on very-short-term load forecasting," in 2015 International School on Nonsinusoidal Currents and Compensation (ISNCC), 2015, pp. 1-6.
2. P. S. Leung and W. Miklius, "Accuracy of electric power consumption forecasts generated by alternative methods: the case of Hawaii," Energy sources, vol. 16, pp. 289-299, 1994.
3. W. Young-min, l. Jong-uk, and j. Sung-kwan, "electric vehicle charging method for smart homes/buildings with a photovoltaic system,"consumer electronics, ieee transactions on, vol. 59, pp. 323-328, 2013.
4. B. Chen, K. S. Hardy, J. D. Harper, T. P. Bohn, and D. S. Dobrzynski, "Towards standardized Vehicle Grid Integration: Current status, challenges, and next steps," in Transportation Electrification Conference and Expo (ITEC), 2015 IEEE, 2015, pp. 1-6.
5. W.K.Wong, M. Xia and W.C. Chu, "Adaptive neural network model for time-series forecasting", European Journal of Operational Research, Vol. 207, No. 2, pp. 807–816, 2010.
6. Z. A. Khan and D. Jayaweera, "Approach for smart meter load profiling in Monte Carlo simulation applications," IET Generation, Transmission & Distribution, vol. 11, pp. 1856-1864, 2017.
7. M. Khashei and M. Bijari, "A novel hybridization of artificial neural networks and ARIMA models for time series forecasting", Applied Soft Computing, Vol. 11, No. 2, ,pp. 2264-2275, 2011.
8. E. Guresen, G. Kayakutlu, Tugrul and U. Daim, "Using artificial neural network models in stock market index prediction", Expert Systems with Applications,Vol. 38, No. 8, pp. 10389–10397, 2012.
9. Jose Maria P. Junior and Guilherme A. Barreto, "Narx reference: Long-Term Time Series Prediction with the NARX Network: An Empirical Evaluation", Neurocomputing, Vol . 71, pp. 3335-3343, 2008.
10. D. Ashok Kumarand S. Murugan, "Performance analysis of Indian Stock Market Indexusing neural network time series model",pp.72–78, 2013. International Conference on Pattern Recognition, Informatics and Mobile Engineering (PRIME 2013), Periyar University, Salem, India, 21st and 22nd February 2013.
11. D. Ashok Kumar and S. Murugan, "Performance Analysis of MLPFF Neural Network Back propagation Training Algorithms for Time Series Data", pp.114–119, 2014. World Congress on Computing and Communication Technologies (WCCCT 2014), St. Joseph's College (Autonomous), Tiruchirappalli, India, February 27, 28 and March 1, 2014.
12. Cecil Bozarth, "Measuring Forecast Accuracy Approaches to Forecasting A Tutorial" ",http://scm.ncsu.edu/scmarticle/article/meauring- forecast-accuracy Date accessed: 08/11/2016.
13. Haijun Chen and Lifeng Wu "A New Measure of Forecast Accuracy" IEEE International Conference on Information and Financial Engineering; 25 October 2010; 978- 1-4244-6928-4.
14. R. Adhikari and R.K. Agrawal, "An Introductory Study on Time Series Modeling and Forecasting", LAP Lambert Academic Publishing, Germany, pp.1-67, 2007.
15. Zafar a. Khan and dilan jayaweera "approach for forecasting smart customer demand with significant energy demand variability" international conference on power, energy and smart grid (icpesg); 14 june 2018; 978-1-5386- 5482-8