Survey on Machine Learning based Electric Consumption Forecasting using Smart Meter Data

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ABSTRACT
The use of smart meter in electric power consumption plays great roll benefiting customer to control and manage their electric power usage. It creates smooth communication to build fair electric power distribution for customers and better management of whole electric system for suppliers. Machine learning predictive frameworks have been worked in order to utilize the electric energy assets effectively, productively and acknowledgment of advanced energy generation, circulation and utilization. This paper presents outline of research works identified with machine learning based forecasting of customers electric power utilization from smart meter data. The paper concentrates on exhaustive study of strategies and relative examination of classifier models utilized as a part of determining customer electric power consumption. Moreover, limitations, difficulties, points of interest and disadvantage of the past works identified with machine learning based methods determining of customers electric power consumption are over viewed.

Keywords
Smart Meter, Machine Learning, Data Analysis, Electricity Forecasting, Support Vector Machine, Artificial Neural Networks.

1. INTRODUCTION
In modern world the use of smart meter for controlling and managing electric power consumption is one of the technologies which helps both customer as well as electric power supplier. It is expected that 70% of the worlds' population over 6 billion people, will live in cities and surrounding regions by 2050, so cities need to be smart [1]. Reliable, efficient and seamless electric power and energy flow are the critical parts to energize and to power services like smart cities, buildings, factories, and transportations. To implement these important services without interruption the knowledge of smart meter and smart energy with the combination of electric power grid plays a great role [2]. Smart Energy has been a critical calculated worldview for future energy utilize, on account of restricted non-sustainable power source assets accessible on Earth and furthermore high cost of obtaining sustainable power sources. Using energy in more efficient and effective way and reducing the power supply-demand gap increases the performance of smart grid system. Effective electric power management and distribution without loss of energy are the most challenges of the current energy grid system. The concept of smart meter and smart grid aims fixing those challenges to providing quality services. Many data analytics researches has been done and need to be done, to provide smart grid with full capability to have fair distribution of electric energy and reduce electric supply-demand gap which in turn takes part in saving global economy.

In this overview previous research works related to forecasting customers electric energy consumption based on machine learning models are presented. The survey highlights methodologies and algorithms used in forecasting customers' electric energy consumption, comprehensive and comparative details to overcome current challenges and to direct future works to come up with efficient and effective utilization of energy with current technologies and global energy plan. The paper is organized in different sections, section 2 deals with related research works focusing on algorithms, models and result obtained, section 3, explains over all summarized view of previous works in tabular form. Section 4 depicts about conclusion and future research areas, references are drawn in section 5.

1.1 Motivation
As the Utility business section is enormously developing inside the Industry and Society area, an ever increasing number of Smart Meters and Smart Grids constantly deployed to urban areas. A recent Allied Business Intelligence Research Study (ABIS) suggests that more than 1.1 billion smart meter bases will have been installed globally by 2021 [3]. The ESM will occupy the largest share, with more than 70% of all installed smart meter bases [4]. On the other hand, in developing countries the shortage of electricity power with poor management of the electric power supply is frequently common, addressing these problems and fulfilling available research gap in the specified filed are the motives of the area of study.

2. LITERATURE REVIEW
Electric Power is the most flexible and broadly utilized type of vitality and worldwide request is developing persistently. In present day life all individuals are customer of Electric power. Electricity can be utilized to feel comfort at home, to cool, to warm, light them, wash garments, cook to eat, to engage and different purposes Currently electric energy distribution and deployment with in smart environment fairly and intelligently faces different challenges. Forecasting customer's electric energy consumption manages and handle challenges that results from currently unbalanced distribution of smart electric energy. Forecasting the electricity consumption by applying different machine learning mechanisms and models is the best approach to save energy as well as economy. Accurate forecasting will empower utility suppliers to design extra assets and furthermore take control activities to adjust the electricity supply and demand. Forecasting electric utilization is an imperative assignment to give insight to smart grid. It includes prediction of maximum

power usage of appliance, peak demand and customers level of life style. Different researchers tried to address challenges of current electric consumption forecasting systems in which some of them are described below.

Lines, Jason, et al [5] Grouping of household unit devices by power utilization profiles by utilizing 15 minute settled time interim of smart meter information, order every household device. Smart meter following and recording of the entire homes of utilization and transmit back to the organizations. Effectively see every device utilization detail and in view of that how to arranging the household device was the point of the paper. The main contribution of the paper was tending to time serious classification issue through determining arrangement of highlights that portray the example of utilization and the measure of energy utilized when a device is on. The capacity to consequently recognize the kind of appliance gives experiences into the breakdown of the household unit utilization design and get the possibility for giving functional reaction of the consumer ,both As far as minimizing their utilization and done issue identification. For grouping correctness they posed applying diverse machine learning classification like k-Nearest neighbour, Support vector machine, and C4.5 and Random Forest. At last the outcome demonstrated that with a week after week profile they could precisely separate between classes of device set of enlightening highlights and random forest or nearest neighbour classifier were a critical systems for precisely give week after week utilization detail however irregular random forest was the better machine learning algorithm by inferring with exactness of over 80% for chilly and 72% for screen amass dataset.

Ning Lu, et al [6] shown breaking down information qualities, removing key information signature and incorporating data of 15 minute information from every single pertinent datum source. The point of the paper was to recognize conceivable information recommendation from smart meter estimation to infer a key information marks for different target applications. Autocorrelation and cross-correlation are procedures used to extricate these key information marks to portray the typicality and variation from the norm use of electric power. The examined result demonstrates that an information signature database can be worked for various time determination informational collections for the smart meter information data management system; at that point various applications can get to the information marks to recognize anomalies in smart operation, customers vitality utilizations, and grid control and correspondence systems .

Adrian Albert et al [7] Smart meter driven division: What your utilization says in regards to you. The paper contribute in various angles whether the individual worldly utilization is sensibly depicted, contrast and group client agreeing with their comparability design and use the derived qualities of utilization to anticipate exogenous attributes (socioeconomic, apparatus stock, and so forth.). As per the investigation arranging customers in view of their closeness was difficult, however they proposed an information driven system that permits predicting user qualities utilizing using only consumption attributes as gathered from the utilization time arrangement. Hidden Markov Model (HMM) and another clustering methods unearthly HMM method to section user's way of life and properties by utilizing information from clients Smart meter information, customers utilization data and their statistic, family unit, and apparatus stock qualities. The outcome uncovers that there is both a lot of consistency in use's state arrangement and impressive variety for gathering certain way of life and appliance stock attributes. Dynamic model of the time arrangement as caught by HMM examination can serve as significant prompts in directing custom fitted mediation.

Tomas Ząbkowskie et al. [8] Short term electricity power forecasting utilizing singular smart meter information. The paper points in exact expectation short term electric power stack utilization with twenty four hours on singular smart meter information from different machine learning techniques connected for estimating for past work at long last they chose utilizing MLP neural system and Support Vector Machine (SVM) on 24 hours customers smart meter information to estimate individuals short term power utilization. The outcome was both machine learning approaches effectively perform great forecast with slightest blunder and satisfactory exactness.

Wei Yu et al. [9] examined Statistical Displaying and Machine Learning Based energy Use forecasting in smart grid. The paper exhibited detail of smart grid vitality utilization estimating used to adjust request supply and compelling administration and control of vitality in the smart grid. Creating measurable demonstrating examination to infer factual vitality appropriation vitality use. Estimating the vitality in smart grid is essential thing for service organizations for arranging extra vitality source, producing new vitality. Generally the Shapiro Wilk test and Quantile-Quantile plot typicality test were connected to explore the measurable dispersion of vitality utilization and the machine learning based methodologies. Those machine learning based methodologies incorporate standard Radial Basis Function (RBF), support vector machine (SVM, the Least Squares (LS) based SVM, and the Backward Propagation Neural Network (BPNN) were created to lead the precise forecasting of vitality utilization. The effectiveness of the created approaches was approved through real world informational index. At long last their result demonstrates that the vitality utilization can be to a great extent approximated with a Gaussian distribution and the SVM based machine learning methodologies could precisely determining the vitality use.

Sudha Gupta et al [10] support Vector Machine Based Proactive Cascade Prediction in Smart Grid Using Probabilistic Framework. The principle commitment of the examination was to catch the pith of the falling disappointment utilizing probabilistic structure and combination of SVM machine learning tool. To build an expectation administer rule which would have the capacity to predict the situations of the power outage as right on time as could be allowed. The proposed model was confirmed by applying the IEEE 30 transport test-bed framework. Finally prediction of cascade disappointment using SVM machine learning approach empowered to predict cascade preceding before huge power outages happen that utilized for proactive cascade prescient in arranging and maintenance of smart grid early cautioning framework.

Kui Wu et al [11] A Machine Learning Approach to Meter Placement for Power Quality Estimation in Smart Grid is another investigation made concerning electric power consumption. The point of paper was lessening the cost of PQ observing in power network. The fundamental contribution of the examination was a system demonstrate for PQ estimation, in view of the device inactive highlights that are found out from a certifiable data set, a savvy entropy-based methods and a Bayesian Network (BN)-based way to deal with tackle the meter situation issue. Nonetheless, it is accounted for that it

was not a simple undertaking, since the power quality estimation devices are expensive and fiscally hard to screen all aspects of energy organize. They portrayed a BN-based algorithm for choosing areas for setting power meters in a power network. The approach uses Monte Carlo (MC) examining and probabilistic inference approaches used to recognize areas in the power grid which displayed unpredictable PQ occasions. At long last, the proposed arrangements fundamentally settled the vulnerability of PQ values on monitored control joins.

Md. Sumon Shahriar et al [12] Urban Sensing and Smart Home Energy Optimization is another machine learning approach research work. The objective of the work was integrating machine learning techniques with data from different urban sensing sensors to exhibit that energy optimization application for smart home. Optimizing the energy obtained from various sources from different urban sensing sensors for effective utilization of energy in smart home was one of the aspects of the researchers to save both energy and economy. M5P algorithms is the machine learning algorithms integrated with the collected dataset for prediction of solar energy for efficient energy management. The outcome of the study shows that combining machine learning algorithms with public data resulted in improving the classification accuracy of traditional models. The study indicates that integrating power features with additional context feature of public data provides 96% of classification accuracy.

David Walkera, et al [13] examined forecasting household water use with information gathered amid the progressing water venture. Determining household water utilization from consumer's water smart meter information was the objective of the investigation. As indicated by the paper forecasting the genuine use of water was used to determine the deficiency of water asset and furthermore used for spillage identification. The ultimate result of the work portrayed two technique a manufactured neural system (Artificial Neural Network) to predict whenever ventures of water use. In next strategy models were prepared using an evolutionary algorithm, with characterizations decided experimentally. The paper additionally acknowledged customers can deal with their assets and economy adequately if appropriate forecasting of water asset is applied.

Joseph Siryani, et al [14] System utilizing Bayesian Belief Networks for Utility Effective Management and Operations utilizing Bayesian Belief Networks is an investigation made on utility administration and operation with help of machine learning procedures. They attempted to show nonspecific predictive examination outline work for choice of effective utility administration operation. Diminishing the utility cost during operation, support and enhancing the general framework administration and operational proficiency, execution and consumer loyalty was the primary objectives of the examination work.

Damminda et al [15] additionally outlined smart electric power meter information knowledge for future vitality frameworks. They introduced exhaustive study of smart electric power meters and their usage concentrating on key parts of metering process, the distinctive partner interests and technologies used to fulfil partner interests. Most generally used metering insight exercises, key difficulties and fate of smart metering was profoundly talked about. Machine learning methodologies of support vector machine, principal component analysis (PCA) and fuzzy rationale techniques were likewise in located in similar approach.

Stephen Haben et al [16] Examination and clustering of residential customers vitality behavioural request using smart meter information is additionally one of the contributors of current research area. The paper experiences profound investigation of customers smart meter information to decide the peak demand and major source of inconstancy in their conduct. The information was analysed in how it is arranged into four time arrangement and 10 unmistakable behavioural of client in light of their request and source of changeability were found by Finite Mixture Model clustering method. The model was at long last assessed using existing bootstrapping methods and the outcome uncovered the grouping was done in the sensible way.

Samuel Idowu et al. [17] applied machine learning: Forecasting heat stack in district heating framework. Information driven approach determining and investigation of both space and water warm vitality use of DHS (water and space warmer around 90% of Sweden people groups using this innovation) was the commitment of the examination. The load figure models were produced using supervised machine learning procedures, specifically, support vector machine, regression tree, feed forward neural system, and different linear regression. They examine was used four key properties the open air temperature, historical values of heat load, time factor factors and physical parameters of region warming substations as its input. The forecasts models were delivered and assessed using information observed from 10 area warming substations serving five multi-family apartment and five business structures. The models are assessed with shifting estimate horizons of consistently from1up to 48h.The applied techniques demonstrate that support vector machine, feed forward neural system and multiple linear regression were more appropriate machine learning strategies with bring down execution error than the regression tree. Among those machine learning techniques Support vector machine approach demonstrates better than average expectation result minimum standardized root mean square mistake of 0.07 for a forecast horizon of 24h.By understanding that each building has its own particular use design conduct notwithstanding working with similar classes.

Thierry Zufferey et al [18] Among the current investigations determining of Smart Meter Time Series in view of Neural Networks (NN) utilizing Support Vector Machine (SVM) or more refined ANNs like Recurrent Neural Network (RNN) and Long Short-Term Memory estimating utility utilization from different sorts smart meter profile. Utilizing single smart meter information or individual is hard to predict and couldn't give successful outcome. Then again by aggregating diverse smart meter information and by dividing in light of time and ANN the work is finished. Standardized Root Mean Square Error (NRMSE) and the Mean Absolute Percentage Error (MAPE) are strategies used to assess the execution of forecasting algorithm. The last outcome uncovers that enhanced exactness has been acquired from commercial and industrial loads rather than individual meter data.

Martinez-Pabon et al.[19] smart meter information examination for excellent customer determination demand response programs .Selecting customer for demand response program is one parts of concentrate in which smart meter information is investigated in light of customers utilization information and way of life choosing customers which who was qualified for Demand reaction program was the point of paper. Smart Meter Data Analytics for Optimal Customer Selection in Demand Response Programs is among such examinations done in late time. These have been utilized for

enhancing age limit and search for different options. Specifically, when appeal is available, the cost of power is higher than amid off-top hours. Utilities encourage clients to move their utilization examples to low-peak hours and advantage from the motivations. The Paper was profoundly contributes predicting qualification to take an interest in DR programs utilizing load utilization attributes of customer. This approach was unique in relation to other such huge numbers of studies .This was the first occasion when they were connected R-programming language for smart meter information investigation. What's more, utilized both order and grouping systems for effectively enlisted customers taking an interest demand response programs those techniques were an agglomerative progressive clustering use for determination of the correct number of groups. And furthermore for best mix of cluster used K-implies. Besides they connected four distinctive machine learning algorithms (K-Nearest Neighbour, choice tree, counterfeit neural system and arbitrary timberland.).To predict enlistment in DR programs in view of household units' power stack profile shape. Those chose customers would have been prepared keeping in mind the end goal to move their peak hour utilization peak on getting to be peak off by utilizing continuous smart meter information. At long last irregular random forest up being an important strategy for the investigation of brilliant meter information for expansive data sets, with an exactness of 95.1%

Joseph Siryani et al [20]. A Machine Learning Decision-Support System Improves the Internet of Things' is the most recent examination made in the area of smart meter information investigation. Smart Meter Operations shows an information driven system to enhance (electric smart meter) ESM operations inside the Internet of Things ecosystem. The proposed work essentially cantered around on decision support system for smart meter operation by using machine learning tools. Enhancing the performance of smart meter during operation and maintenance stage by reducing travel expense cost was also the contribution of the study. They showed the productivity of their approach with complete Bayesian Network expectation model and compare with three machine learning prediction model classifiers: Naive Bayes, Random Forest and Decision Tree. At last their result demonstrates that Random forest technique had the most elevated expectation precision of 96.69 about whether to send a specialist to a customer's site or resolve the case remotely.

3. TABULAR SUMMARY OF THE PREVIOUS RELATED RESEARCH WORKS

Forecasting customers electric consumption based on machine learning approach constitutes supportive advantages both for supplier and customers in managing and reliable usage of electric energy. The concept of smart metering is adaptively added to help in simplifying the recording and measuring of daily usage of each customers consumption with respect to its requirement and cost. To handle challenges and maintain flexible and smart usage of electric energy detail analysis of smart meter data analysis is highly required in expert level. Different works has been done to satisfy the forecasting and to maintain reliable management of customers' electric energy consumption. Among many research works some of them are described in the following table of "table" 1.

Table 1: Summary of related literature Reviews

Title of the paper	Author's (year)	Publisher	Method	Limitation	Results
Classification of household devices by electricity usage profiles	Jason Lines (2011)	Intelligent Data Engineering and Automated Learning-IDEAL	• K-NN • SVM • C4.5 and • Random forest	- Effect of seasonal data not considered	- The result showed that random forest provides better accuracy than others.
Smart meter data analysis	Ning Lu, (IEEE, (2012)	Transmission and Distribution Conference and Exposition (T&D), 2012	• Autocorrelation • Cross correlation	-Correlation among multiple data sources didn't focused.	-The result shows that a data signature database can be built for different time resolution data sets to manage smart meter datasets
Smart Meter Driven Segmentation: What Your Consumption Says About You	Adrian Albert , IEEE (2013)	IEEE Transactions on Power Systems2 8.4	• Hidden Markov Model • clustering algorithms	-influence of weather consumption was not fully addressed	-Depending on the consumers usage information the study was able to predict users life style and attribute

Short term electricity forecasting using individual smart meter data,	Tomasz Ząbkowskie Elsevier (2014)	Procedia Computer Science35	• MLP neural network • SVM based on	-Since they used individual smart meter data, time series analysis is not included	-The result was both machine learning approaches successfully perform good prediction with least error and acceptable accuracy.
Towards Statistical Modelling and Machine Learning Based Energy Usage Forecasting in Smart Grid	Wei Yu (2015)	ACM	• standard Radial Basis Function • support vector machine • Backward Propagation • Neural Network (BPNN)	-Not found	- Finally their outcome shows that the energy usage can be largely approximated with a Gaussian distribution and the SVM based machine learning approaches could accurately forecasting the energy usage.
Support Vector Machine Based Proactive Cascade Prediction in Smart Grid Using Probabilistic	Sudha Gupta(2015)	IEEE	• Probabilistic framework integration with SVM	-Other failures not fully addressed like cause of suspicious or malicious attack	Finally prediction of cascade failure using SVM machine learning approach enabled to predict cascade predicting prior to massive blackouts happen.
Urban Sensing and Smart Home Energy Optimizations: Machine Learning Approach	Md. Sumon Shahriar ,(2015)	ACM	• using M5P	-Event detection from other sources for energy efficient planning was not addressed.	-Integrating power features with additional context feature of public data provides 96% of classification accuracy.
Forecasting Domestic Water Consumption from Smart Meter Readings	David Walkera,(2015)	Elsevier	• ANN • Models were trained using an evolutionary algorithm	-The magnitude of consumption in peak demand couldn't predict accurately.	-The final outcome of the work an artificial neural network to predict the next time steps of water usage.
Framework using Bayesian Belief Networks for Utility Effective Management and Operations	Joseph Siryani,(2015)	First International Conference EEE	• Bayesian Belief Networks	-Predicting risks and performance concerns prior to the occurrence didn't concerned	The result shows increase the Utility complex systems cost efficiency during the network operations and maintenance lifecycle.
A Machine Learning Approach to Meter Placement for Power Quality Estimation in Smart Grid	Kui Wu(2016)	IEEE Transactions on Smart Grid	• Bayesian Network-Based • Conditional Entropy-Based Approach	-They didn't addressed other related activities	Finally, the proposed solutions significantly resolved the uncertainty of PQ values on unmonitored power links
Analysis and clustering of residential customers energy behavioral demand using smart meter data	Stephen Haben*,(2016)	IEEE transactions on smart grid	• Finite Mixture Model clustering algorithm • Bootstrapping for validations	-They didn't incorporate the significant of low carbon technologies into the clustering	Existing bootstrapping technique they show that the clustering is reliably segment maximum demand and source of variability.
Applied machine learning: Forecasting heat load in district heating system	Samuel Idowu ,(2016)	Energy and Buildings Elsevier	• Support vector machine, regression tree, feed forward neural network, multiple linear regression.	-They didn't apply additional parameters like Grey-box models	-Among those machine learning methodsSupport vector machine approach shows decent prediction result least no-realized root mean square error of 0.07 for a forecast horizon of 24 h.

Forecasting of Smart Meter Time Series Based on Neural Networks	Thierry Zufferey,(2016)	Data Analytics for Renewable Energy Integration. Springer.	• SVM or more sophisticated ANNs like RNN Long Short-Term Memory	They used only single weather data	The final result reveals that improved accuracy has been obtained from commercial and industrial loads rather than individual meter data.
A Machine Learning Decision-Support System Improves the Internet of Things' Smart Meter Operations	Joseph Siryani,(2017)	IEEE Internet of Things Journal 2	• Bayesian Network • Naïve Bayes • Random Forest • Decision Tree	-customer-case solutions were not predicted - Did not apply for additional vertical operations	-Finally their outcome shows that Random forest method had the highest prediction accuracy of 96.69%.
Smart Meter Data Analytics for Optimal Customer Selection in Demand Response Programs	Martinez-Pabon, (2017)	Energy Procedia	• agglomerative hierarchical clustering • Nearest Neighbor • Decision tree • ANN • Random Forest	-Customers PV panels were not taken into account	Finally random forests proved to be a valuable method for the analysis of smart meter data for large datasets, with an accuracy of 95.1%.

4. CONCLUSION AND FUTURE WORK

More stable and exact forecasting of power utilization is profoundly critical for reserving money vitality and decreasing carbon emanation. It is a reality that smart meters are digging in for the long haul and that the smart grid and smart metering will be a 'lifestyle' later on. This paper overviewed research works related to forecasting customer's electricity consumption using data from smart meter by applying various machine learning techniques. This paper reviewed investigate works identified with determining client's power utilization utilizing information from brilliant meter by applying different machine learning procedures. The paper features different ideas of anticipating clients' electric utilization, distinctive techniques, algorithms, models and summary of results applied by various studies related to forecasting customer's electric consumption is clearly emphasized. The requirements of effective utilization of energy resources with the help of smart meter data needs brief study and deep analysis in the research area. Showing directions for scholars to work on detail analysis and building valuable forecasting systems results in successful distribution with effective utilization of electric energy resources. Since the area under research is new and recently addressed many studies are required in a wide range to fill full the research gaps. Among the research gaps integrating low carbon technology with newly devised forecasting system is one the research works to be done by scholars. Incorporating other energy sources like solar energy, heat and wind energy with electric energy for efficient forecasting and utilization is another part of future work.

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