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Prediction of Future Electric Energy Consumption using Machine Learning Framework

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Abstract*: In the last few years, the expanding energy utilization has imposed the formation of solutions for saving electricity. Of many solutions, one is generating a power saving policies which is defined as prediction of energy in smart environments. This model is built, based on the idea that the building residences are provided with smart meters to monitor energy consumption and can be managed accordingly. Recent prediction models focuses on performance of the prediction, but for developing a reliable energy system, it is required to predict the demand taking into account different scenarios. In this paper we propose a model for predicting future demand for energy according to different conditions using advanced machine learning framework. In this system we have a projector that builds proper state for a particular condition and using that defined state a future power demand is forecasted by the predictor. The proposed model generates utilization predictions for every 2 hours. Demonstrating the electricity consumption data for 5 years, the proposed system achieves a better performance.

Keywords: Electric energy; energy management system; energy consumption forecasting; energy prediction; machine learning.

I. INTRODUCTION

The worldwide exploitation of electricity is growing rapidly due to increasing human population, great use of electronic equipment to improve the standard of living, prominence given to large scale industrialization, and the emphasis on keeping the positive economic growth. For the economic development of any country, electric energy has become an important input and also predicting the consumption. Forecasting consumption of electric charge is one of the most crucial areas of electrical engineering, it plays important role in economic operation and performance of energy system. Studying the load energy demand is necessary in studying and planning future consumption of electricity appropriately. In last few years, development of electricity demand forecasting models using machine learning have been of great interest.

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An energy management system has been designed to manage the demand for rapidly increasing energy. Lot of studies have been done by many researchers, and are involved in algorithms to predict future energy trends of various countries using different prediction approach. Electric energy consumption prediction is essential for analyzing the load characteristics and determining the factors affecting it. Achieving high prediction speed and accuracy is an important aspect for any power production companies to schedule its energy resources appropriately and create optimal bidding plans in the market. In electric power systems many different prediction techniques have been used for achieving accuracy. Electric energy consumption with machine learning has been widely used because of its high performance and accuracy.

II. LITERATURE REVIEW

In this paper [1], they proposed a model for predicting the future power demand according to different situations by making use of deep learning model which was based on automatic encoder. The system consisted of a projector that determined the state according to various conditions and a predictor that predicted the power requirement for that particular state. This model produced forecasts for the consumption for 15, 30, 45, 60 minutes with a 60-minute demand to date.

In this paper [2], they proposed a CNN LSTM hybrid network that extracted space-time information for predicting house power consumption efficiently. This hybrid networks linearly combines CNN and LSTM, and is capable of extracting the unusual i.e uncommon features of energy consumption of electricity. The convolutional neural network layer was used to minimize the range of space information, and the long short term memory layer was useful in analyzing the time information, and the predicted time series was generated by the DNN layer.

In this study [3] they used deep learning techniques in the environmental field for predicting degree of pro-environmental consumption. Recurrent neural network model was used to predict the pro-environmental consumption index, which was formed from the data of search query of the Google. For verifying the correctness of pro-environmental consumption index, comparison was made between the prediction accuracy of this model with that of the artificial neural network models and ordinary least squares. The pro-environmental consumption index was predicted more effectively with RNN model than any other model.

This study [4] combined SAE with the ELM, taking benefits of their specific characteristics. In this approach, the Stacked Auto Encoder was taken into account to extract features of power usage of buildings, while the Extreme Learning Machine was used as predictor for estimating exact values of predicted energy. They used partial autocorrelation analysis method for determining input value of variables of the extreme deep learning model.

In this paper [5], author tried to put into context the magnitude of increasing consumption of energy in various growth scenarios of human and economic development. While it is said that the scenarios reflect excessively optimistic hypotheses, they represents the growth levels to reduce the level of bias among its citizens. However, studies showed that to get upto the assumed growth levels, the energy consumption levels required were beyond the capacity of available conventional energy sources. Considering the amount of the population increase in developing countries, the increase in energy is much less than the demand. Therefore, there is a need for international awareness and commitment about increasing energy use and implementation of realistic plans to address this problem.

The goal of the work [6] is to interpret the users of residential energy consumption in Lithuania and compare energy saving techniques in terms of potential of power savings and cost in buildings of Lithuania. Trying to reach the goal of the main work activities they must analyze the theoretical questions of the main users of residential energy usage, analyzing residential energy, using trends in Lithuania and compare it with that of other States. They defined the main drivers with the use of residential energy by applying correlation analysis; analyze policies to lower the utilization in residential buildings and their impact on reducing greenhouse gas emissions.

This study [7] accounts a review of body of research knowledge linked to green construction. Common research themes and various methods have been identified. The themes of these municipalities are denotation and extent of green building, assessment of the advantages of ecological buildings compared to non-ecological buildings, and different perspective of constructing an ecological building. There exist studies carried out, focusing mainly on environmental aspect of green building. Future research scope has been identified as the outcome of climatic conditions on the efficiency of green building, quantification, verification of the performance of ecological buildings.

In this paper [8], a neural network algorithm SVM (support vector machines) was introduced, to estimate the power consumption of buildings in tropical locale. Here, the main aim was to inspect the applicability and feasibility of SVM in load forecasting for buildings. For case study, they randomly selected 4 commercial buildings in Singapore. Three input features viz. relative humidity, weather data considering the dry bulb temperature and global solar radiation were selected. To develop and test the model, the mean monthly utility bills of landlords were collected.

This paper [9] introduced an approach based on human dynamics analysis derived from aggregated and anonymized data i.e telecom data, to predict the energy consumption of next week, which is calculated from network CDR(Call Data Records). They analyzed the consistency in the source data, provided a perception on the feature extraction method and discuss about the anomaly or abnormality in regression models appropriate for this big data problem. This model was able to act on energy producers and energy distributors as an necessary help to smart meter data for decision making to reduce the annual basic utilization of energy, by restricting the production of energy when demand is not known and to minimize the distribution cost of energy by systematic planning on buy side and provide an insight into geographical space for maximum load planning.

This paper [10] suggests that feature engineering helps reduce the dimensionality of data, decrease the complexity of model, and handling situation of noisy and corrupted data. Assuming that every building has distinct operating characteristics, it is not practically and logically efficient to manually identify the features for development of model. Using the real building's operational data, they investigated the efficiency of various deep learning methodologies that instantly derive high quality features for building's energy prediction. This study states the usefulness of deep learning in enhancing power prediction performance of the building.

In this paper [11], modular recurrent neural network (MRNN), a deep learning algorithm was used for predicting the electric vehicle energy requirements from various data available inside the vehicle. This model used various parameters and data from the electric vehicle such as power requirements of electric motor considering various driving parameters. Power requirements of other devices in the vehicle were also taken into consideration while modeling the system. Using MRNN, a deep learning algorithm; which was used to train the network to predict the power requirements and providing optimal power, enhanced the driving range. Moreover, this MRNN algorithm makes the power prediction of vehicle very smooth and avoided jitters in the training phase.

[12] This is a review paper that states, Machine learning methods have recently contributed to a large extent in the advancement of the prediction models used for energy consumption. Machine learning models highly improve the accuracy, robustness, precision and the generalization ability of the conventional forecasting tools. Through a novel search and taxonomy, the most relevant literature in the field is classified according to various Machine learning modeling techniques, type of energy, type of perdition, and the application area. Along with the conventional ML methods, the application of hybrid and Ensemble methods have been dramatically increased. Through hybrid and ensemble methods the researchers aim at higher efficiency and accuracy.

III. PROPOSED METHODOLOGY

To the field of application, we propose to solve power demand forecasting, using the advanced machine learning algorithm.

A. System Architecture

The overall architecture of our model consists of raw electric energy data with consumption data and time data. A feature like weather information is also taken into consideration.

Also, the time of the day (morning, afternoon or evening) is been taken into account. Proposed work presents, advanced feature selection and prediction algorithm for power consumption prediction, trying to improve the accuracy using this technique. Fig. 1 shows the overall architecture of our system.

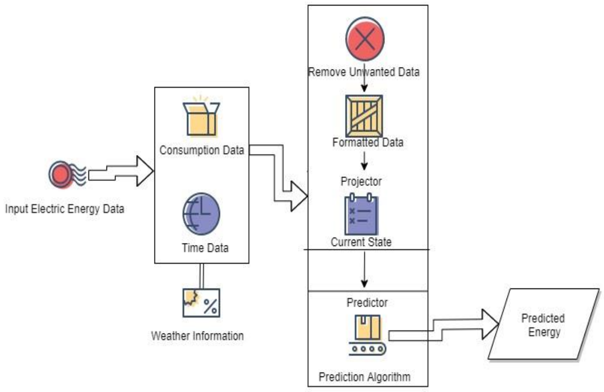

Fig. 1. Proposed System Architecture

B. Mathematical Model

The Mathematical model for energy prediction system is

S= {I, F, O}
Where,
I = Set of energy dataset
The input consists of a set of features.
F = Set of functions
O=electric energy prediction
F= {F1, F2, F3, F4}
Where,
F1=Data Collection
F2=Data Preprocessing
F3=Feature Selection
F4=Classification

C. Algorithm

Random Forest Algorithm:

Step 1: First, start with the selection of random samples i.e. the random subset of feature values (Time and Weather) from a given dataset.

Step 2: Next, this algorithm will construct a decision trees for every sample (each subset of energy dataset attributes). One subset of attributes will be taken at a time to construct decision tree. Many decision trees will be formed.

a. Decision tree uses tree representation for solving the problem, here internal node of the tree contains dataset attributes like date, time etc and each leaf node corresponds to a class label.
b. At the beginning, we consider the whole training set as the root and construct the decision tree.
c. Feature values are mostly categorical. Features values are discretized if the values are continuous, before building a model.

Step 3: In this step, energy prediction will be performed by each decision tree. Prediction will be according to various conditions, like time of the day, different seasons etc.

Step 4: At last, select the most predicted result by all decision trees, as the final prediction result.

IV. RESULTS AND DISCUSSIONS

Table -I shows the RMSE values of previous studies on Energy Consumption Prediction using various Machine Learning Algorithms.

Table- I Performance Metrics of Various Techniques

Dataset	Algorithm	Year	RMSE(Root Mean Square Error)
https://archive.ics.uci.edu/ml/datasets/individual+household+electric+power+consumption	Auto-encoder	2019	0.6196
https://archive.ics.uci.edu/ml/datasets/Appliances+energy+prediction	Semi-SVM	2019	0.8612
https://archive.ics.uci.edu/ml/datasets/individual+household+electric+power+consumption	CNN-LSTM	2018	0.395
https://trynthink.github.io/buildingsdatasets/	Extreme SAE	2017	22.9
https://www.kaggle.com/ijfezika/mobile-phone-activity-exploratory-analysis	CDR	2016	18.0352
https://openei.org/datasets/dataset/residential-energy-consumption-survey-results-total-energy-consumption-expenditures-and-intensiti	SVM BPNN RBFNN GRNN	2010	2.395 14.462 12.440 5.237
https://data.gov.sg/dataset/building-energy-performance-data	SVM	2004	4

RMSE is the standard deviation of the residuals i.e prediction errors. RMSE is the measure of, how spread out these residuals are.

The formula for calculating RMSE is

$$RMSE_{fo} = \left[\sum_{i=1}^{N} (z_{fi} - z_{oi})^2 / N\right]^{1/2} \quad (1)$$

Where:

Σ = summation ("add up")
$(z_{fi} - z_{oi})^2$ = differences, squared
N = sample size
f = forecasted values.
o = observed values.

Fig. 2 Shows the expected RMSE(Root Mean Square Error) for small subset of dataset. RMSE of the dataset for the two hours data is 0.3338.

```
Correctly Classified Instances         396              87.2247 %
Incorrectly Classified Instances        58              12.7753 %
Kappa statistic                          0
Mean absolute error                      0.2241
Root mean squared error                  0.3338
Relative absolute error                100      %
Root relative squared error            100      %
Total Number of Instances              454
```

Fig. 2. Expected MAE & RMSE for a small dataset

Fig. 3 below shows the graph of the performance of the random forest in comparison with the previous model.

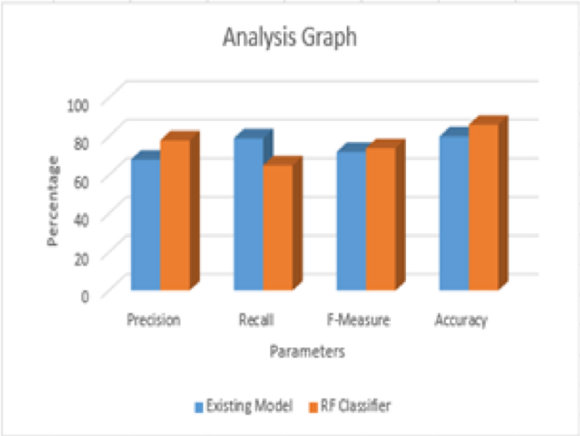

Fig. 3. Performance Analysis Graph

Dataset Used:
https://archive.ics.uci.edu/ml/datasets/individual+household+electric+power+consumption.

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed an efficient predictive model that can be described by predicting the energy demand for future, according to various conditions and also defining the state as current energy demand patterns. This model will be able to predict a very complex energy demand value with stability and increased performance, as compared to studies done previously. The state determined by the model is analyzed by the system and it evaluates a model that is capable of predicting the future power requirements. Conditions taken into account are weather and time of the day. The model can be extended for predicting the power demand according to more different conditions like economy etc.

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