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Renewable power source energy consumption by hybrid machine learning model

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Machine Learning;
Energy Consumption;
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Multilayer Perception;
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Abstract Today, electricity is in high demand in a variety of places, including hospitals, industry, households, transportation, and communication, among others. Renewable energy is a revolutionary type of energy that is increasingly being used to replace electricity demand because it has been regenerated and reused several times. Renewable energy is an intermediate and unpredictable natural resource, so it is difficult for many research studies to estimate its rate. To address this problem, this study uses a hybrid machine learning technique to precisely predict the energy level of natural resources. The hybrid machine learning is the combination of Multilayer Perceptron (MLP), Support Vector Regression (SVR) and CatBoost algorithm that increases the performance and predictability of renewable energy consumption. The proposed system dataset's results are evaluated at the train and test levels, and the results are then compared to other current approaches. The end results reveal that the proposed hybrid machine learning technique has a high prediction level when compared to others, as well as a lower cost rate and improved overall system performance.

1. Introduction

Renewable resource is the fast-growing energy source which can be used to replace the conventional energy. The resource that can be regenerated is known as renewable energy. This is defined as the source of energy that cannot be depleted and which can be supplied continuously as a source of clean energy. The most frequently asked question about the renewable resource is their sustainability. It is necessary to provide enough energy to meet the needs. It is necessary to know how long the energy can be used, some natural resource can be regenerated automatically this includes solar power, wind power, tidal power and geothermal energy. The radiation forms the sun is uses as the source of power an then they are converted into electric energy [1]. Certain amount of energy is used to run the power calculator and these powers are combined together and drive to the solar panel to produce the pollution energy Pollution can be avoided using the renewable energy and greenhouse gas emission this contribute to climate change. As the renewable resource produce pollution free energy, they are known as the clean energy. There are certain challenges related in using the renewable resource such as less dependable than non-renewable resource, climatic condition [2].

In recent years, the research about the power sector has been spreading over the world. To forecast the opportunities and challenges in the power load the deep learning technology

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has played an important role. The main task of the power system is to deliver safe and dependable power supply to the consumers. There is considerable significance for the power sector. Forecasting the accurate power is needed for saving the energy and reducing the cost of power generation and this improve the social and economic benefits. It is necessary to increase the power demand forecasting accuracy in the power system this also provide the stable and efficient operation [3]. Coal, oil, natural gas, fossil fuels, nuclear, minerals are some types of nonrenewable resource that cannot be regenerated at a short period of time. At the same time the rate of consumption of such fuels is too high and there is great demand. For example, fossil energy is limited and dry up but still it has a high price demand and the rate of these fuel is increasing day by day. Suppose it these energies are exhausted it can not be bringing back in future. Hence, the world is shifting towards the renewable resource such as wind energy, waterpower and solar energy. Greenhouse gas is not emitted and the risk of greenhouse effect is reduced [4]. Renewable energy has become the normally preferred energy solution. Solar and wind energy can gradually keep pace with traditional energy source. On the other hand, the fact that renewable energy is affordable, low-carbon, environmentally friendly and reliable and consumers in emerging market and enterprise have continuously increased their demand for renewable energy.

Due to the effect of the climatic change, there is a need to run back towards the developing technology. According to the International Energy Agency, 65% of the greenhouse are originated from the energy segment and this signifies the transformation of the energy area. The main role in decarbonization is played by renewable energy and 66% of gas is emitted from the global station. Some research includes a deep implementation process for further development in the renewable energy source [5]. Various type of methods was used in predicting the energy consumption of renewable resource. Some technology was used to predict the flood predicting during data mining. Energy consumption is calculated for each building this shows whether the energy has to be increase or not. In some countries, the population growth increases the energy consumption gradually. The increase in the energy consumption rate may also increase the fossil fuel rate which may include coal, natural gas ad fuel oil.

To overcome the significant challenges during the development of energy consumption statistical analysis and learning methods were used to overcome. Computation cannot be proceeding by statical analysis when a large feature dataset is providing. Compare to the other method statical analysis is too weak it can only compute the time series and high similarity level. To provide better performance in computation and prediction the machine learning technology is used and the drawback in machine learning is overcome by hybrid machine learning [6]. The missing data and interconnectivity problems during computation can be overcome by the hybrid machine learning technology. Short-Term forecasting is predicted using five methods in machine learning. In this, the support vector regression method provides clear computation during the prediction and estimation of the dataset. It is a basic statistical learning method and it is classified base on two types of classes to find optimal hyperplane. The calculation of accuracy and prediction in machine learning were processed by various types of methods. In this method, support vector regression and the Catboost algorithm were used to predict the energy consumption of renewable resource sources using the hybrid machine learning method.

Renewable energy source is raising at a high peak and it is integrated with non-conventional into electric grid to meet the demand on the energy requirement. At a time of series, the power data are considered as the historical data set and collected as the sample record at particular time period. Artificial Intelligence and soft computing play an important role in gaining more reliable energy. To solve the problems in energy application theses tool has proven the source that solve the problem in energy crisis application. To overcome the significant challenges during the development of energy consumption statistical analysis and learning methods were used to overcome. Computation cannot be proceeding by statical analysis when a large feature dataset is providing. Compare to the other method statical analysis is too weak it can only compute the time series and high similarity level. To provide better performance in computation and prediction the machine learning technology is used and the drawback in machine learning is overcome by hybrid machine learning [6]. The missing data and interconnectivity problems during computation can be overcome by the hybrid machine learning technology. Short-Term forecasting is predicted using five methods in machine learning. In this, the support vector regression method provides clear computation during the prediction and estimation of the dataset. It is a basic statistical learning method and it is classified base on two types of classes to find optimal hyperplane. The calculation of accuracy and prediction in machine learning were processed by various types of methods. In this method, support vector regression and the Catboost algorithm were used to predict the energy consumption of renewable resource sources using the hybrid machine learning method. Because air pollution, climate change, water pollution, thermal pollution, and solid waste disposal are all environmental challenges directly tied to energy generation and use, predicting the rate of renewable energy sources is difficult. The major goal of the research is to accurately anticipate the energy generated by renewable energy sources. This method employs hybrid machine learning techniques such as the Multilayer Perceptron (MLP), Support Vector Regression (SVR), and CatBoost algorithm to improve the performance and predictability rate of renewable energy consumption in challenging times.

The paper provides a detail view on renewable energy prediction. Introduction of renewable energy resource and the algorithm in predicting the energy consumption is expressed in section1. The related work of the existing algorithm is presented in section 2. System model and the basic concept used in the paper in explained in section 3. The proposed method is explained in section 4 with an algorithm and the flowchart with the processed involved in predicting the energy consumed. Simulation analysis is present in section 5 as Result and discussion. The last view is conclusion about the overall method.

2. Related work

To focus on the preprocessing system using feature engineering and to improve the prediction level [6] has proposed a method on machine learning. This method is based on a hybrid system for assertion and the prediction of efficient energy demand. The dataset collected from South Korea is used for testing purposes and hourly calculation is done. The hybrid model over-

comes the disadvantage of the different machine learning models. Using the gap in the dataset the prediction is done and both the model set are used for computing. To validate the test data the final dataset is used and it again prosed for computation. Thus, the validation for prediction is carried out. The paper only defines the estimation of the dataset using a hybrid model but the accuracy of the prediction rate is not defined in machine learning. Only a small number of datasets can be estimated. [7] proposed a method to define the integration of renewable resource and energy storage system. Microgrid connection is used with hybrid energy storage to provide the probable benefit between the end user and the system operator. This method uses two-layer EMS to perform the function. Batteries and capacitors were used for generating power in the microgrid and power fluctuation occurs due to RES. The effectiveness is improved by utilizing the energy stored for the other purpose. The main disadvantage of this method is it requires a high capital coat for implementation.

The ambient energy is integrated with the wireless sensing nodes for harvesting purpose and to overcome the limited battery power budget. This had extended the effective use of the sensor operation in network. The light energy is frequently collected by using the solar panel and used by the wireless sensor node. Energy prediction in solar power harvesting technique is introduced by [8]. The paper provides the algorithm of efficient energy saving properties. Both the summer and the winter season and various climatic conditions were considered to perform the operation. Prominent terms were used to estimate the change in the climate. To avoid the climatic change the solar power harvest is used for seven days and the process is noted. 72 slots were used and each slot were harvested in solar power for 20 mints. Each slot rate energy is noted and then the power of the energy is noted. The algorithm used in this paper is compared with the existing algorithm and the prediction rate of the solar power is observed. This paper predicts the energies is separate level and the seasonal change and recent trends were noted and the total sum of prediction is estimated.

A hybrid algorithm for short-term solar power prediction is proposed by [9]. Based on the combination of gradient-descent optimization methods the forecasting algorithm has been proposed. Along with the gradient-descent model, the *meta*-heuristic optimization model and artificial neural network is used. The ANN is used in identifying the optimal parameter during the application training. Each model performs different operation and it's too complex to perform the computation. The major disadvantage is implementation of different method is needed to predict the energy consumption. This determines the estimation of electricity using wind power. The progress timing is too long when compared to other method. A new input method selection procedure proposed by [10] which combines the GMDH with bootstrap method. For short-term hourly forecasting the support vector regression method is used and under same experimental condition GMDH has to be constructed for number time and finally the SI input layer is selected for the experimental purpose. This method needs relevant dataset to contribute the random division of learning. For the comparison purpose the LS and MI type of filters are used. The disadvantage of this method is single network is created to yield the partial input result. The non-linear relationship was taken as the input in and GMDH network compares the potential input and output. Long process in needed for computing the process and filtering.

An extension in gradient boosting algorithm which leads to speed and accuracy is determined in this paper. The paper is about the comparative analysis of gradient boosting algorithm [11]. This demonstrates the reliable and efficient challenges in the machine learning techniques. The XGBoost technique enable the process and this is mostly focused on the providing fast performance. To avoid the prediction shift and to improve the efficiency the CatBoost algorithm is modified to provide perfect computation property. Using the XGBoost, LightGBM, CatBoost, random forest and gradient boosting method tuned carefully to perform at high rate. General accuracy is obtained using the CatBoost algorithm. They were used as the alternative tool for the traditional statistical model techniques and this is one of the forms of neural network system [12].

A hybrid forecasting model based on a machine learning technique is created by stitching together the supervisory learning algorithms such as RBF SVR, LSBDT, and ELM. Due to data loss during grid failure events and malfunctioning monitoring instruments, the historical dataset utilized to create such prediction models is prone to missing data and outliers. The missing data problem has been addressed in this study using a linear regression model that imputes missing data [20]. The four different forecasting models, support vector machine, linear regression, extreme learning machine, and artificial neural network, were trained on the training dataset and then evaluated on the test dataset to anticipate energy consumption in the oil and gas industry. To improve the accuracy of energy consumption forecast, the combinations of all four models were tested using the RMSE value, which was calculated by averaging the outputs of two models. The results reveal that these four alternative models are capable of accurately predicting energy usage. To regulate oil field energy consumption and enhance efficiency, the hybrid model is placed in the energy management system of the oil and gas industry [21].

Four levels, including the data collecting layer, the preprocessing layer, the prediction layer, and the performance evaluation layer, have predicted the energy. Each layer's data is subjected to various procedures. The deep extreme learning (DELM) approach was utilized in the prediction layer to improve the accuracy of the energy consumption prediction. The DELM increases the number of hidden layers in the original ELM network structure, arbitrarily initializes the input layer weights and the initial hidden layer weights. Finally, the output network weights are calculated using the least square algorithm. To determine the best number of hidden layers trial-and-error approach is used. An adaptive neuro-fuzzy inference system (ANFIS) and an artificial neural network (ANN) were used to evaluate the suggested DELM model's performance in terms of energy consumption prediction [22]. Table 1 shows the comparison of advantages and disadvantage of previous works.

The advantages and disadvantages of various learning algorithms are compared. The proposed system addresses the shortcomings of earlier studies and anticipates energy from renewable sources.

The key contribution of our research is summarized as,.

The data was gathered from the International Energy Agency and evaluated using the train-test split approach. To improve the performance and predictability rate of renewable energy consumption, hybrid machine learning approaches such as Multilayer Perceptron (MLP), Support Vector Regres-

Table 1 Advantages and disadvantage of previous works.

Reference	Methods	Advantage	Disadvantage
[6]	Machine Learning	Prediction level high for small datasets	Small number of dataset can be estimated
[7]	Micro grid connection with two-layer EMS	Different types of energy storages can be utilized	High capital cost for implementation
[8]	Solar Power Harvesting Technique	Maintenance cost low	Computation time is large
[9]	Gradient-Descent Optimization and forecasting algorithm	Low cost for implementation	The computation is complicated and progress time is excessively long.
[10]	GMDH with Bootstrap Method	Prediction accuracy high	Long process is required for computing and filtering
[11]	Gradient Boosting Algorithm	Speed of the performance is high	High Cost for implementation
[12]	XGBoost, LightGBM, CatBoost, random forest and gradient boosting method	Highly flexible and faster the Gradient Boosting Algorithm	Many methods are used for implementation High Cost & take more time for implementation
[20]	RBF SVR, LSBDT, and ELM	Missing data can be addressed	Take long time to predict the energy
[22]	Deep Extreme Learning (DELM)	Complicated Data can be processed	Long process is required for computing energy

sion (SVR), and CatBoost algorithm are utilized. This suggested hybrid machine learning approach uses a large number of datasets to predict power. The accuracy of the forecast is high, the computation time is short, and the implementation cost is minimal.

3. Problem statement

Climatic changes have caused problems in predicting the energy consumed and the cost performance is high. Machine learning process increases the time speed and the accuracy rate is not predicted properly. Most of the existing method use only solar power as the alternative source of conventional type of energy. In this method different type of renewable energy are used as the alternative source and high power is produced. The cost rate can reduce by combining different algorithm. So, to improve the rate of prediction and reduce the electricity supply the CatBoost algorithm and multilayer perception were used. This could increase the overall performance of the system.

4. System model

4.1. Hybrid Machine learning

One of the most games changing technology in the recent year is machine learning. In the rapidly growing cooperation, the machine learning enables the companies to attain the expected outcome at fast manner. Combining two different types of machine learning method leads to the development of hybrid machine learning method. Machine learning is divided into two part they are supervised learning, unsupervised learning and reinforcement learning. Each learning method has its own advantage and disadvantage. The supervised learning is one of the basic method machine learning methods. The accurate labeling data set is needed in this method. This method helps in improving the algorithm and the relationship between the training and new data set. The unsupervised learning has the advantage of working under the condition of unlabeled dataset. This provided the post-deployment development than supervised learning algorithm. The reinforcement inspires the life of the humans. This program is set to provide possible solution to the given data. This work under the both the labeled and unlabeled condition. The full process algorithm for estimating energy from renewable energy sources is depicted in Fig. 1.

The data is gathered from renewable energy sources and processed, after which the training and validation data can be identified. The data is then passed through a hybrid machine learning algorithm, after which the output value is checked for errors, and the final output has a high accuracy and low error rate.

4.2. Multi-Layer perception

Multi-Layer Perception is session of feedforward artificial neural network layer. It is a fully connected layer and the term MLP is used ambiguously, strictly and even loosely in the ANN field. The multi-layer perception is divided into three layer they are.

- Input layer
- Output layer
- Hidden layer

Each node in the network is connected to any one of the layers. The output layer and hidden layer uses the nonlinear activation technique. The input layer uses the linear activation techniques. Supervised learning technique is used by he MLP and this termed as the backpropagation method. Application such as speech recognition, image recognition uses the multilayer perception technique.

4.3. CatBoost algorithm

CatBoost algorithm is an open source of machine learning algorithm from Yandex. This is an integrated from of deep learning network system, this can be worked with different type of data. This is used in wide range of access to provide prefect accuracy. The feature of CatBoost algorithm is.

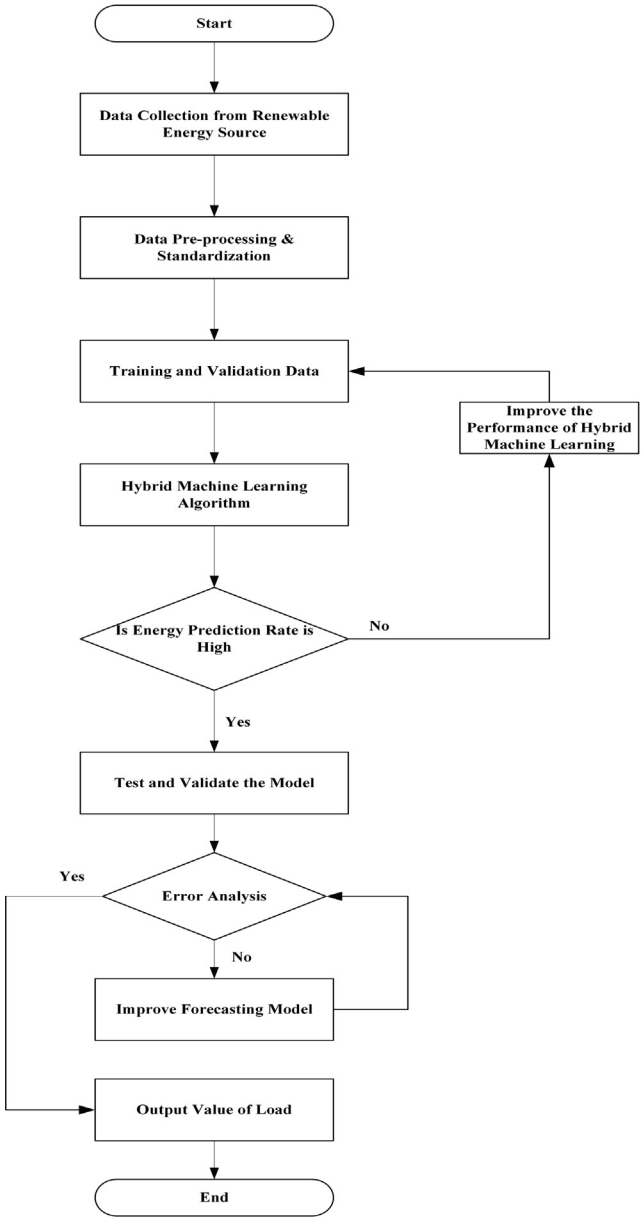

Fig. 1 Algorithm for the entire process through hybrid machine learning.

- Without parameter tuning great quality is obtained
- Categorical Feature Support
- Improved Accuracy
- Rapid Prediction

Three steps are used in the CatBoost algorithm such as ordered boosting to overcome fitting, native handling for categorical feature and using symmetric tree execution technique.

4.4. Train and test

The dataset is classified into two system they are test and training sets. Training data set is collected from different years. The energy load consumption pattern is the set of input data series. The training data contain the set of data which includes hour, day, month and yearly data consumption pattern. Predicting the future based historical and current data is termed as forecasting. This describes the problem and the actual time series data set.

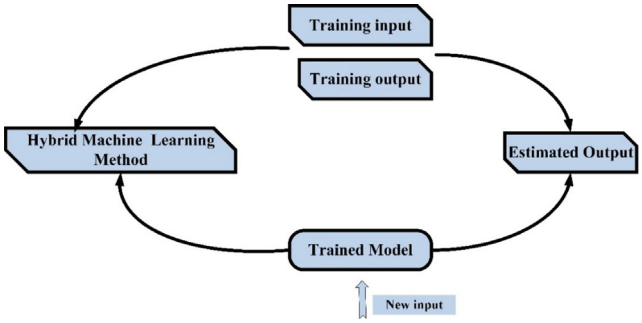

Fig. 2 Basic Structure of Energy Prediction.

4.5. Predicting system

Power predicting is used to explain how much does a company or by the consumers and the balance demand of the power supply. The combined load data of renewable and non-renewable energy resource is used to predict the energy consumption. A detail of data analysis, pre-processing and train-test split method were used to predict the energy consumed in the system.

5. Proposed method

It is a challenging task to predict the energy consumed in a building or in surrounded area. The main risk during predicting the energy is weather condition, thermal properties etc. A large number of efforts has been taken to overcome the risk in predicting the energy consumed in the system. Machine learning method and artificial intelligence play an important role in predicting the energy consumed in an area. Hybrid machine learning is widely used in the energy sector for forecasting the energy load. The hybrid leaning method select the load of the past period of timing as the training model, particular algorithm is selected to train the data network and the structure of the network is designed [13]. The Fig. 3 shows the flow of proposed predicting strategy. At first the two-power source i.e. renewable and nonrenewable resource are taken. Without any contract the nonrenewable resource is collected form the small size solar energy system contract means behind the meter (BTM), photovoltaic (PV) or solar energy and wind power (WP) [14]. To analysis the trend data exploratory data analysis (EDA) is performed. The dataset is split into training and test set after the preprocessing technique. The training data set is processed to the hybrid model, the hybrid model contains three basic function they are CatBoost, Support Vector Regression and multilayer perception. To validate the model the test dataset us used. Different error metrics were used to analyze

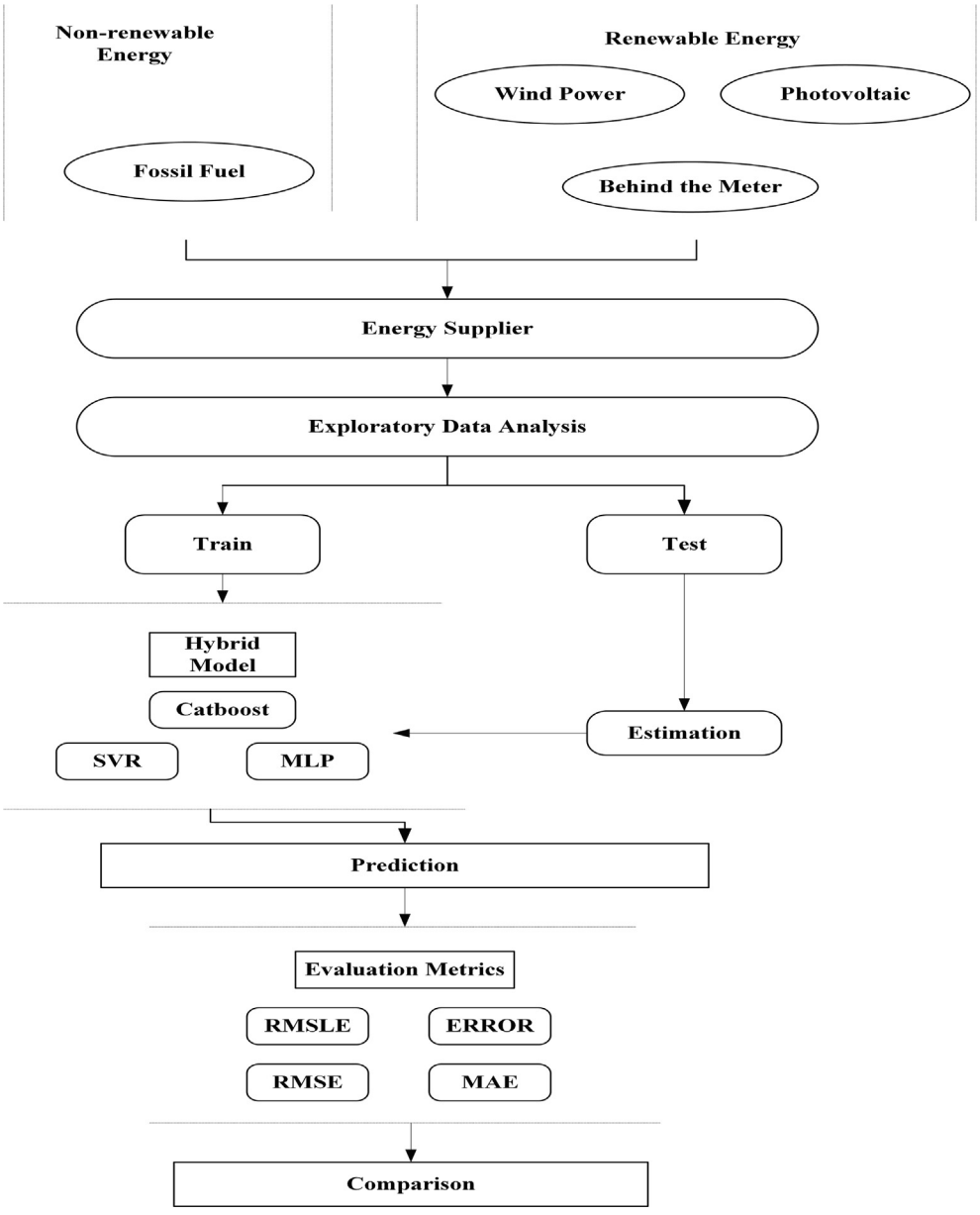

Fig. 3 Flow Diagram of the proposed predicting Method.

the performance of the system model. Thus, the predicted result is obtained and then compared with the existing machine learning method [15–19].

The above Fig. 2 represent the energy prediction level this involves dataset, training set, learning algorithm and machine learning model and prediction system. The training dataset is divided into two part they are training input and training output data set. The data set in the training part is passed to the hybrid machine learning method in which the three basic concept function is carried out and then passed to the training model and the trained model produce the predicted output. The above figure explains the basic structure of energy predicting system using the machine learning mechanism.

Algorithm.

Algorithm: Prediction of Energy Consumption

Input: Renewable Energy Data (R), temporal rationality and data range condition (TD)
Output: Predictable data set (P)
Algorithm Flow
For each machine tool a
For each process b
For each data field c
If the data array $R_{a,b,c}$ satisfies a condition TD_t where $TD_t \epsilon TD$
If $R_{a,b,c}$ is not predicted

Algorithm (*continued*)

Algorithm: Prediction of Energy Consumption

// Store this data array into SD
P ← $R_{a,b,c}$
End if
End if
End for
End for
End for
Return SD

The aim of machine learning is to train a stable model that perform well in all features but it remains ideal in some situation. The process of combining multiple deign model to obtain a better and comprehensive model in supervised process is known as ensemble learning. When wrong prediction is obtained and the classifier can improve the mistake is the fundamental idea of ensemble learning. The hybrid machine learning method improve the performs and the prediction level by combining the MLP, SVR and CatBoost method. This could help to provide improved prediction in energy consumption.

The Fig. 3 shows the flow diagram of the proposed predicting method. The overall flow in the proposed method is described in the diagram. The renewable and the nonrenewable resource are combined together and passed to the energy supplier in which the combined energy is supplied and the total load energy is estimated and the passed to the exploratory data analysis process. The data analysis process is divided into two process they train and test. The training process leads to the hybrid model and the test level led to the estimation state. The hybrid model contains three basic models namely, CatBooost, SVR and MLP. The estimation process led to the hybrid model and then they combine together to the prediction state. From the prediction state the evaluation metrics is calculated and the comparison of existing method.

6. Result and discussion

For the experimental purpose the actual energy consumption data from the year of 2012 to mid-2020 is collected. The energy source wise dataset is summarized in Table 2. the count of each data source, mean, standard deviation, minimum and maximum load is provided.

The Fig. 4 shows the graphical representation of wind power. The Fig. 5 shows the graphical representation of solar power and the Fig. 6 indicates behind the meter graph and the Fig. 7 shows the comparative prediction of renewable and nonrenewable energy. In wind power system the energy has increased gradually and reached a peak at 2015 and then slowly decreased at 2016 and then again start to increase. The solar power has increased and reached a high peak at 2020.

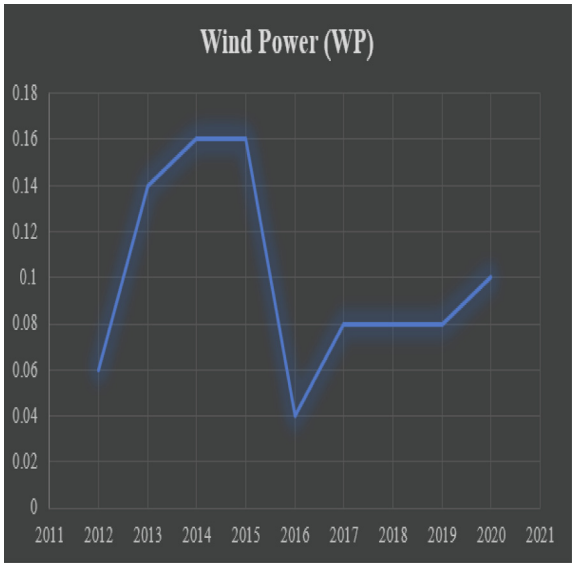

Fig. 4 Wind Power (WP).

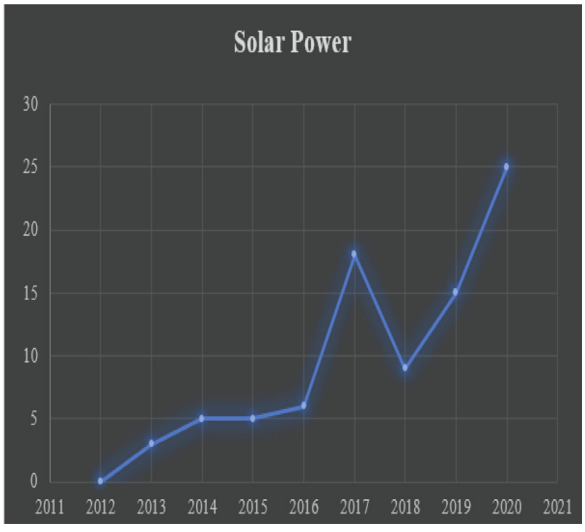

Fig. 5 Solar Power.

The Fig. 8 shows the graphical representation of predicting renewable energy. the data is collected form the year 2011 to

Table 2 Energy Source Data Summary.

Parameter	Count	Mean	Standard Deviation	Minimum Load	Maximum load
Fossil Fuel	72,836	486.00	100.55	110.10	965.50
Wind Power	72,836	0.0350	0.0277	0.00	0.1564
Behind the Meter	72,836	0.8115	2.5196	0.00	24.267
Photovoltaic	72,836	0.8547	2.2240	0.00	26.235
Total	291,344	121.925	49.4922	0.00	965.50

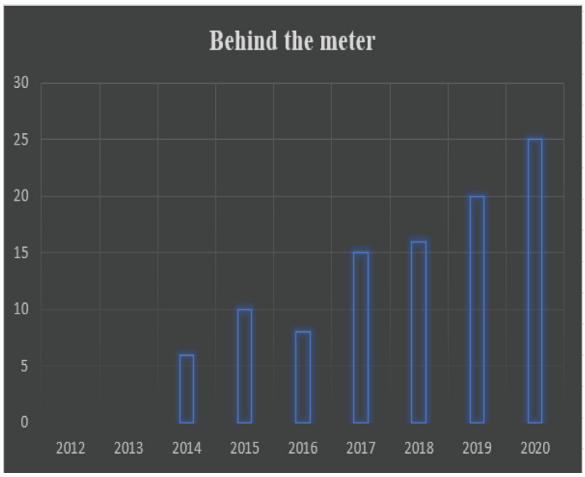

Fig. 6 Behind the Meter.

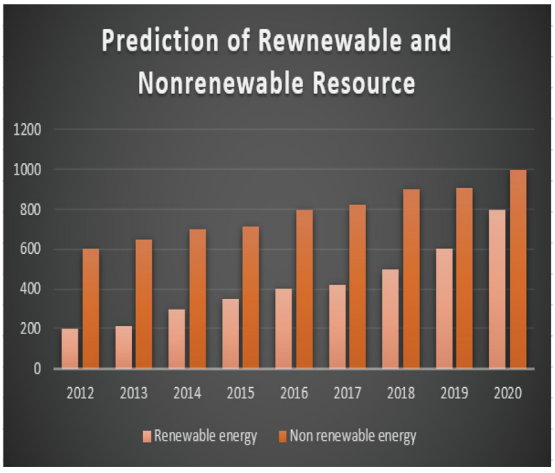

Fig. 7 Prediction of Renewable and Non-Renewable Resource.

2020. The rate of prediction is increased gradually. The hybrid model helps to find the prediction rate at correct accuracy. The energy consumed in each ear is predicted using the hybrid model the basic concept of MLP and CatBoost algorithm is used to predict the energy in the given area. Thus, the above graphical representation gives a clear view of energy consumption and the comparative process of renewable and nonrenewable resources.

Fig. 9 shows the Energy demand in 2000 to 2020. The data set is collected from International Energy agency (IEA). This shows the energy demand of coal, oil, natural gas and modern renewable resource. Compared to every year 2020 had a high demand on energy and the total demand on the energy during 2020 is about 880 Mtoe. The modern renewable energy is also increased in 2020 when compared to 2019. Every energy rate is increased in the 2020 nearly the gap of 20 years difference calculated and illustrated in Fig. 9 energy demand. The Table 3 shows the prediction and error rate of proposed method with existing method.

The proposed Hybrid Machine Learning accuracy and error rate is compared to other recent works. The result shows that the proposed method has high prediction accuracy with low error rate.

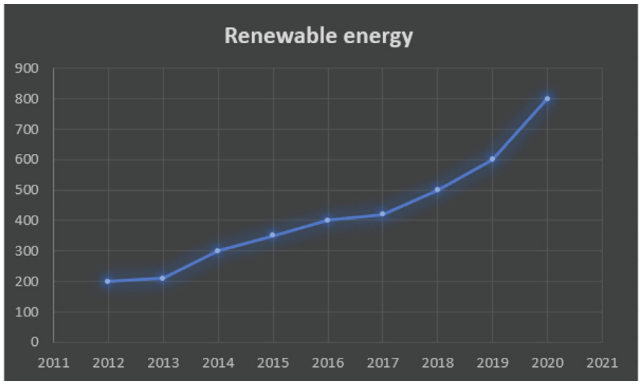

Fig. 8 Prediction of Renewable Energy.

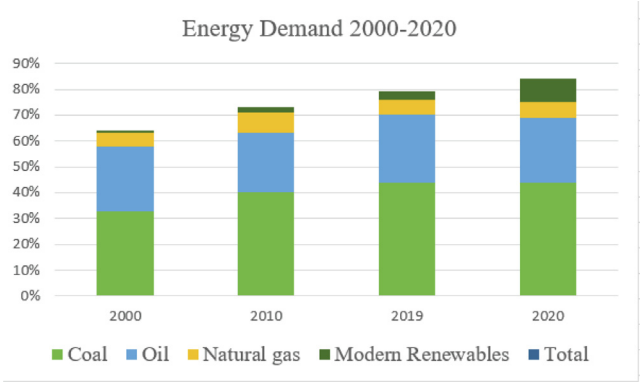

Fig. 9 Energy Demand 2000–2020.

Table 3 Comparison of previous work with proposed work accuracy and error rate.

Methods	Prediction Accuracy Rate	Error Rate
Machine Learning	Medium	High
Micro grid connection with two-layer EMS	Medium	Medium
Solar Power Harvesting Technique	Medium	Medium
Gradient-Descent Optimization and forecasting algorithm	Medium	High
GMDH with Bootstrap Method	Medium	Medium
Gradient Boosting Algorithm	Medium	Medium
XGBoost technique	Medium	Medium
Proposed Hybrid Machine Learning	**High**	**Low**

7. Conclusion

Renewable resource plays an important role in generating electric power. So, it is necessary to predict or forecast the energy in the given area. The data set collected form International Energy Agency gives the clear view of renewable resource and the electric power consumed in the India. In this paper the prediction of renewable energy is done using hybrid machine learning method. The CatBoost, Multilayer Perception and Support Vector Regression were used to predict the energy consumed. The forecast energy and error rate will be

compared to those of other methods that are currently in use. The results reveal that the suggested hybrid machine learning model was successful in forecasting energy from renewable sources. This provides accurate prediction results with low error rate. The dimensionality reduction technologies are combined with a hybrid machine learning approach, the prediction rate can be improved without error in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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