A REVIEW OF LOAD ESTIMATION AND DISTRIBUTION STRATEGY FOR RENEWABLE ENERGY SOURCES

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Abstract—**The remarkable increase in per capita power consumption worldwide has drawn attention towards the needed growth in renewable energy sector in order to bridge the gap between overall demand and supply. In this project various renewable energy sources like solar, wind and hydro energy are taken into consideration for the load estimation. Several factors are considered for the making of dataset related to each energy source which include environmental factors as well as other supporting factors. With the collected data, prediction of energy generation is performed using the machine learning algorithm, Random Forest. The generation, transmission and distribution of the energy is achieved through a power grid system which enables efficient and reliable supply of electrical power from power plants to various consumers.**

Bidding mechanisms are commonly used in renewable energy markets to allocate and trade energy generated from renewable sources. Producers, such as solar farms or wind power facilities, participate in bidding processes to sell their energy to different distribution centres through grid. Bids may include details like the quantity of energy, pricing, and timing of delivery.

Keywords- Renewable energy integration, machine learning algorithms, power spot market bidding, block chain-based energy market, solar energy profiles.

I.INTRODUCTION

In the ever-evolving landscape of renewable energy, the precise estimation and effective distribution of loads constitute crucial facets for optimizing resource utilization. Addressing this imperative, advanced algorithms and sophisticated bidding mechanisms are combining to revolutionize load estimation and distribution within the realm of renewable energy sources. Aligned seamlessly with the concept of Time of Use (TOU), this approach embraces a forward-looking energy consumption strategy that harmonizes economic and environmental considerations. At its core, the model utilizes robust algorithmic intelligence to precisely estimate energy load demands, adapting dynamically to environmental variables and consumption patterns. The introduction of a cutting-edge bidding mechanism facilitates competitive auctions, ensuring the selection of the most efficient and sustainable energy sources. Departing from conventional approaches, this system tailors load distribution based on the unique characteristics of each renewable energy source, optimizing utilization and enhancing overall resilience. Integrating the Time of Use (TOU) concept, the model aligns with temporal variations in energy demand, promoting efficient resource use and cost-effectiveness. Real-time monitoring and adaptation further ensure the system's responsiveness to fluctuations, maintaining a reliable and sustainable energy supply. As the global push for sustainable energy intensifies, this model, with its amalgamation of algorithmic intelligence, bidding mechanisms, and TOU integration, not only addresses current challenges but also propels the energy landscape toward a smarter and more resilient future.

II. STATE OF THE ART

(A) PREDICTION: MACHINE LEARNING ALGORITHMS

Alvarez, et al.[1] focuses on implementing an efficient renewable energy selection method, specifically for solar and wind energy, based on the geographic location of Aguascalientes, Mexico, using Machine Learning (ML) algorithms. The study involves rigorous data measurements over a period of six months, including solar irradiance, temperature, wind speed, and wind direction, to predict future weather conditions. The ML algorithms used in the study include Support Vector Machines (SVM), Linear Regression (LR), Neural Network Models (NNM), and Random Forest. The Random Forest algorithm was found to be the most accurate in predicting solar irradiance and wind speed, with minimal Mean Square Error (MSE) and Mean Absolute Error (MAE). The technology used in this paper demonstrates the potential of ML algorithms in accurately predicting renewable energy production, which could lead to significant cost reductions and greater value in the energy market. However, the study does not extensively discuss the limitations or challenges associated with the implementation of ML algorithms in renewable energy prediction.

Abdul Khalique Shaikh, et al.[2] delves into the development of a model for predicting short-term energy consumption using the N-BEATS interpretable method. It addresses challenges in energy consumption prediction, particularly data uncertainty and limitations of existing algorithms. By handling data uncertainty through pre- processing to enhance deep learning algorithm performance, the proposed model aims to improve accuracy in energy consumption forecasting. The research discusses the significance of accurate energy consumption prediction for future demand planning in smart grid environments and the utilization of machine learning, specifically neural network- based methods, for this purpose. The model's uniqueness lies in its ability to handle consumption data from multiple customers, making it reliable for diverse customer profiles. A comparative analysis with other deep learning algorithms such as LSTM, interpretable LSTM, GRU, interpretable GRU, and TCN showcases the N-BEATS model's success in accurately and efficiently handling time series data. In conclusion, the paper underscores the importance of addressing data uncertainty to enhance energy consumption prediction models and emphasizes the potential of the N- BEATS interpretable method in advancing prediction accuracy and reliability in smart grid applications.

Meng Z, et al.[3] focuses on predicting energy consumption trends in China using the Support Vector Regression (SVR) model and Markov Chain analysis. The study addresses the challenges of forecasting energy consumption due to the nonlinear nature of the energy system and the limitations of traditional prediction approaches. The SVR model, a supervised machine learning model, is highlighted for its ability to handle regression problems and outperform other machine learning approaches in terms of generalization. The research methodology involves data collection, identification of factors influencing energy use, preprocessing of data, and the development of a prediction model using the SVR model. The study compares the accuracy of the SVR model with the Grey Model (GM) and Moving Average (MA) models. The findings provide insights into the projected changes in China's energy consumption structure during the 14th Five-Year Plan period. Policy implications based on the research findings include the need for scientific regulation of the energy consumption elasticity system, reforming the energy consumption structure, increasing investment in clean energy, and advocating for energy conservation and emission reduction. The study also emphasizes the importance of regional energy consumption management strategies and prioritizing the sustainable development of natural gas. Overall, the paper contributes to the understanding of energy consumption forecasting in China and provides recommendations for policymakers to address energy security, promote sustainable development, and reduce carbon emissions.

Alejandro J. del Real, et al.[4] explains the application of deep learning techniques, specifically a mixed architecture of convolutional neural network (CNN) and artificial neural network (ANN), for energy demand forecasting in the French grid. The study demonstrates superior performance compared to traditional methods and existing subscription- based services. The deep learning model achieved a Mean Absolute Percentage Error (MAPE) of 1.4934%, outperforming linear regression, regression tree, support vector regression, ARIMA, and ANN models. The proposed approach shows consistent accuracy throughout the year, with notable improvements during late autumn and winter seasons. Additionally, the model's generalization performance was validated by testing on randomly selected days, showing alignment with reference RTE forecast data. The study concludes that the deep neural network structure is well-designed, trained, and generalizes effectively for accurate energy demand forecasting.

Rashmi Bareth1 Anamika Yadav, et al.[5] presents a study focusing on utilizing Long Short-Term Memory (LSTM) models for per day average load demand forecasting in Chhattisgarh, India. The research aims to forecast monthly electricity demand by processing and organizing historical load data from 2018 to 2022 for training and testing phases. During the training phase, the LSTM model is trained using data from 2018 to 2022, with input from 2018 and 2019 to predict load demand for 2022. The testing phase involves forecasting load demand for July to

December 2023 based on historical load patterns. Performance evaluation is conducted using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE), with MAE ranging between 3.675 MW to 46.319 MW during training and MAPE ranging from 0.010% to 0.652%. The LSTM model outperforms Artificial Neural Network (ANN) models in load demand forecasting, demonstrating lower MAE and MAPE values. The study concludes that the LSTM-based model provides accurate load demand forecasts by analyzing historical load data patterns, with superior accuracy compared to existing methods, making it suitable for real- time load demand forecasting applications.

Xifeng Guo, et al.[6] focuses on a novel approach to short-term load forecasting by incorporating demand response (DR) into the modeling process. The study addresses the challenges faced in load forecasting, such as rough feature engineering and low prediction accuracy, by proposing a model that leverages LSTM neural networks and considers the impact of DR. Key points covered in the document include: Feature Extraction: The study uses data from New South Wales, Australia, from 2006 to 2010 for experimental verification. Input features extracted for the model include maximum temperature, minimum temperature, average temperature, date type, and real-time electricity price. The weighted method is employed to process multiple input features, enhancing the contribution of effective features and exploring their potential value. This approach aims to improve prediction accuracy and model generalization ability. Optimization with Improved Genetic Algorithm (IGA): The study utilizes IGA to select optimal model parameters for the LSTM neural network. By defining weights for input features and selecting the best model parameters, the model aims to enhance its forecasting performance. Performance Evaluation: The proposed model is evaluated based on its prediction accuracy and computational efficiency. Comparative analysis shows that the model outperforms other methods in terms of accuracy and calculation speed. Experimental Results: The experimental results demonstrate the effectiveness and superiority of the proposed method in short-term load forecasting. The model shows better accuracy and robustness compared to traditional forecasting models like SVM and RF. Overall, the document highlights the significance of considering demand response in load forecasting models and showcases the potential of LSTM neural networks in improving prediction accuracy. The proposed model offers a promising approach to address the challenges in load forecasting and shows potential for practical application in energy management systems.

(B) BIDDING AND SETTLEMENT

Cai, Tingting, et al.[7] presents the Distributed Adjustable Load Resources and Settlement (DALRS) model, which aims to enhance bidding in the power spot market for renewable energy systems. The technology used in this paper includes strategic optimization models for bidding strategies, distributed allocation method-based resource bidding mechanism, and advanced metering and real-time communication in a smart grid. The DALRS model offers a method for developing power supplier energy market bidding strategies and resource bidding allocation techniques to maximize overall benefits. The paper discusses the benefits of smart grid technology, such as improved energy efficiency, environmental friendliness, and the potential to reduce the demand for additional generation sources. However, the paper also addresses challenges, such as security concerns related to cyber-attacks on the grid as it becomes more automated. Overall, the paper provides insights into the potential of smart grid technology and renewable energy systems, while also acknowledging the need to address security challenges and ensure the efficient implementation of new technologies

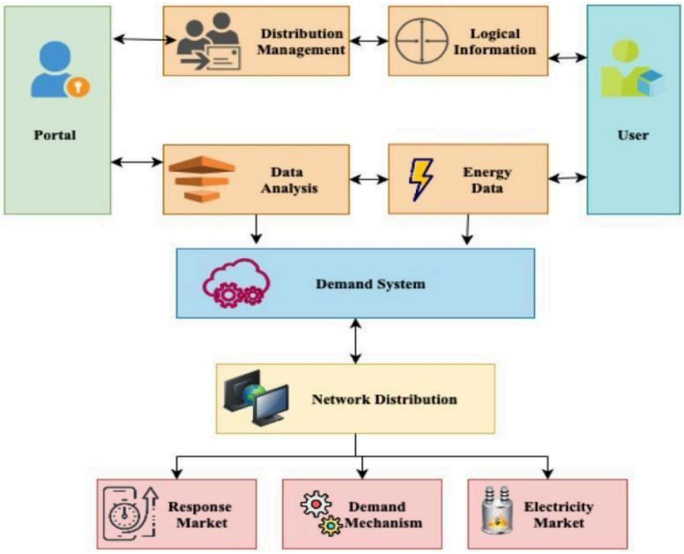

Fig. 1. Framework on market bidding strategies[7]

J. Dargan, N. Gupta, et al.[8] proposes a model for integrating block chain technology into the energy sector, specifically focusing on the management of renewable and sustainable energy sources within the Indian context. The technology used in the paper includes block chain, smart contracts, and the Ethereum platform. The proposed model aims to create a decentralized, secure, and transparent energy management system that enables peer-to-peer energy transmission and trading. The merits of this approach include enhanced transparency, traceability, and security in energy transactions, as well as the potential to create a low carbon global economy and sustainable ecosystem for energy management. However, the paper also acknowledges the demerits of block chain technology, such as its high energy consumption for mining and the absence of finalized regulatory policies in many countries, including India. The integration of block chain technology with existing government schemes and the need for scalability and interoperability with other technologies are also highlighted as areas for future work.

Vivek Patel, et al.[9] delves into the application of Blockchain technology in the energy sector, focusing on wholesale electricity distribution, peer-to-peer energy trading, and electric vehicle charging infrastructure. The analysis considers various parameters such as decentralized trading, smart contracts, resource optimization, cybersecurity, and data privacy to evaluate the potential benefits of Blockchain in addressing challenges in the energy industry. By enabling direct energy transactions, promoting renewable energy adoption through microgrids, and enhancing cybersecurity measures, Blockchain technology emerges as a transformative solution for improving efficiency, transparency, and sustainability in energy management. The document also underscores the significance of Blockchain in India's energy sector, emphasizing its potential to drive energy efficiency, reduce transmission losses, and support the transition to renewable energy sources, highlighting the role of blockchain in shaping the future of energy distribution and management.

Shirin Vakil, et al.[10] discusses how blockchain technology is transforming the oilfield services sector and the energy industry as a whole. It highlights the challenges faced by the industry and the potential for blockchain to address issues related to security, trust, transparency, and efficiency in transactions. The document explains that blockchain is a shared electronic ledger that is reliable, secure, and immutable, allowing multiple parties to access and manage it. By leveraging blockchain, companies can execute and record transactions with unprecedented reliability and achieve optimal transparency in sharing information. The document also emphasizes the importance of blockchain in creating trust mechanisms that can replace traditional methods such as relationships, legal contracts, and third-party intermediaries. Furthermore, it explores the potential applications of blockchain in optimizing asset management, enhancing supply chain visibility, and reducing costs in the energy sector. Overall, the document underscores the disruptive potential of blockchain technology in revolutionizing the energy industry and driving innovation in various processes.

Muhammad Shoaib Arshad Khan[11] provides a comprehensive analysis of the transition from centralized energy systems to distributed renewable energy systems, focusing on the potential integration of blockchain technology in the energy sector. The research work includes a historical review of energy systems, highlighting the importance of energy sharing in a smart grid energy market and addressing the challenges associated with renewable energy distributed generation. The study primarily relies on a literature review approach, analyzing peer-reviewed articles, conference papers, consultancy reports, company websites, and government policy papers to evaluate the current state and future trends in energy systems. By examining theories and practical use cases, the paper aims to identify research gaps, patterns, and areas for further exploration in the field of blockchain technology in energy systems. Key aspects discussed in the thesis include the role of blockchain technology in enabling peer-to-peer energy trading, the significance of smart grids in renewable energy integration, and the potential solutions blockchain can offer in the energy market. The limitations of the study are acknowledged, such as the nascent stage of technology and the lack of commercially successful peer-to-peer energy trading models. Overall, the thesis provides valuable insights into the evolving energy landscape, emphasizing the transformative potential of blockchain technology in shaping the future of energy systems.

A. Boumaiza[12] discusses the application of blockchain technology in energy trading, focusing on its potential to create a decentralized and efficient system. It highlights the inefficiencies in the current energy trading market due to intermediaries and complex processes. Blockchain offers solutions by eliminating intermediaries, streamlining data collection, reducing costs, and improving transparency and security. The document also mentions real-world examples of blockchain being used in small-scale energy projects, such as WePower in Estonia and Power Ledger in Australia. Additionally, it addresses the regulatory hurdles and challenges in implementing peer-to-peer energy trading using blockchain technology. The PDF emphasizes the benefits of blockchain in reducing credit risk, improving efficiency, and enabling the integration of renewable energy sources into the energy trading market.

Technology Used	Accuracy			Error Rate	
	High	Medium	Low	High	Low
SVM			✔	✔	
RF	✔				✔
LR	✔				✔
MLP	✔				✔
SVR	✔				✔
GM	✔				✔
MA	✔				✔
DNN		✔		✔	
RNN		✔		✔	
GRU		✔		✔	
LSTM	✔				✔
N-BEATS	✔			✔	
RTE			✔	✔	

Table 1. Comparison between model

III. MAJOR EVALUATION

PREDICTION ANALYSIS TABLE

Sl,No	Model Used	Duration	Demand Accuracy	Error Rate
1.	SVM	1 YEAR	27%	68.966
	RF	1 YEAR	99%	0.0125
	LR	1 YEAR	97.15%	2.71
	MLP	1 YEAR	99.86%	0.13
2.	SVR	2013-2020	99.7%	0.1412
	GM	2013-2020	92%	3.76
	MA	2013-2020	99.95%	0.0237
3.	DNN	30 DAYS	76.5%	23.5
	RNN	30 DAYS	77.6%	22.4
	GRU	30 DAYS	77.5%	22.5
	N-BEATS	30 DAYS	97.75%	22.5
4.	DEEP LEARNING STRUCTUR E	1 YEAR	92.41%	7.59
	RTE	1 YEAR	25.5%	97.45
5.	SVM	6 MONTHS	86.2%	0.1862
	PROPOSED MODEL	6 MONTHS	90.99%	0.0901
	RF	6 MONTHS	87.41%	0.1259
	GRU	6 MONTHS	89.85%	0.1015
6.	LSTM	6 MONTHS	96.67%	3.33

Table 2. Prediction Analysis

This table presents the performance metrics of different machine learning algorithms in predicting energy production and consumption. Here,
- Random Forest (RF) achieved an accuracy of 87.41% with a Mean Absolute Error (MAE) of 0.125.
- Gated Recurrent Units (GRU) model demonstrated an accuracy of 89.85% with a MAE of 0.101.
- Long Short-Term Memory (LSTM) model outperformed the other algorithms with an accuracy of 96.67% and a MAE of 0.033.

These results indicate that the LSTM model showed the highest accuracy in predicting energy consumption, making it a promising choice for accurate forecasting in energy management systems.

IV. CONCLUSION

The paper delves into the critical aspects of load estimation and distribution strategy for renewable energy sources, emphasizing the importance of optimizing resource utlization in renewable energy sector. By incorporating advanced algorithms and sophisticated bidding mechanisms, the paper showcases a forward looking approach to energy consumption that balances economic and environmental considerations. The integration of Time of Use(TOU) concepts and algorithmic intelligence enables precise energy load estimation, adapting dynamically to variables and environmental patterns.

Furthermore, the paper highlights the utilization of machine learning algorithms such as Support Vector Machines, Random Forest and Gradient Boosting to model energy output from various renewable sources like solar, wind and hydro[1]. The approach not only enhances the efficiency of energy generation prediction but also demonstrates the advantage of applying blockchain technology and smart grid integration in the renewable energy industry[8]. The proposed blockchain-based system aims to facilitate reliable, efficient, safe and transparent transactions in the power spot market, providing stakeholders with recommendations for improving load estimation, energy management and market bidding procedures within a smart grid framework[7].

Moreover, the paper addresses the challenges such as security concerns related to cyber attacks on automated grids emphasizing the need to ensure the secure implementation of new technologies in the energy sector. By exploring the potential of smart grid technology and renewable energy systems, while acknowledging security challenges, the paper underscores the importance of creating decentralized, secure, and transparent energy management systems to enable peer-to-peer energy transmissions and trading.

V. ABBREVIATIONS

SVM	Support Vector Machine
RF	Random Forest
LR	Linear Regression
MLP	Multi-Layer Perceptron
SVR	Support Vector Regression
GM	Grey Model
MA	Markov Model
DNN	Deep Neural Network
RNN	Recurrent Neural Network
GRU	Gated Recurrent Units
N-BEATS	Neural basis expansion analysis for interpretable time series
RTE	Re`seau de Transport d'Electricite`
LSTM	Long Short-Term Memory

Table 3. Abbreviations

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