IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⪤ Peer-reviewed & Refereed journal ⪤ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

ENERGY CONSUMPTION ESTIMATION

Ms. Alisha Ujwala[1], Ms. Bhagyashree[2], Ms. Lakshmi U Kurubara[3], Mr. Mohammad Aman[4], Mrs. Krathika A[5]

Assistant Professor, Department of Computer Science and Engineering, A J Institute of Engineering and Technology, Mangaluru[5]

Students, Department of Computer Science and Engineering, A J Institute of Engineering and Technology, Mangaluru[1-4]

Abstract: Early fault detection in power electronic systems (PESs) to maintain reliability is one of the most important issues that has been significantly addressed in recent years. Fault detection in PESs, data mining-based techniques including artificial neural network, machine learning, and deep learning algorithms are introduced. Electrical energy has become an influential factor in the scientific, economic and welfare fields of human daily life. In recent years, the expansion of electrical energy applications and the increase of electrical energy consumers have made distributed generation (DGs) dramatically replace traditional power systems. Then, the fault detection routine in PESs is expressed by introducing signal measurement sensors and how to extract the feature from it. Finally, based on studies, the performance of various data mining methods in detecting PESs faults is evaluated. The results of evaluations show that the deep learning-based techniques given the ability of feature extraction from measured signals are significantly more effective than other methods and as an ideal tool for future applications in power electronics industry are introduced. The system is developed the different classification algorithm such as artificial neural network and random forest for predicting or detecting the fault in power systems effectively.

Keywords: Energy Consumption Estimation, Data Mining Algorithms, Power Electronic Systems (PESs), Fault Detection, Distributed Generation (DGs), Machine Learning Deep Learning.

I. INTRODUCTION

"Energy Consumption Estimation" involves the application of data mining algorithms play a crucial role in energy consumption estimation, contributing to the precision and effectiveness of predicting, analyzing, and managing energy usage. In the context of energy consumption, data mining techniques are applied to large datasets to extract meaningful patterns, trends, and relationships, enabling informed decision-making and efficient resource allocation. Nowadays, electrical energy has become an influential factor in the scientific, economic and welfare fields of human daily life.

In recent years, the expansion of electrical energy applications and the increase of electrical energy consumers have made distributed generation (DGs) dramatically replace traditional power systems. On the other hand, DGs such as renewable energy sources (RESs) and energy storage systems have been widely used to reduce fossil fuel consumption and solve environmental problems. But the important point is that the production, storage and utilization of electrical energy in the economic and daily life cycle require power electronic systems (PESs).

PESs have a significant role in integrating RESs, energy management, and reliability of power grids, and other related infrastructures and systems. Energy/power conversion using PESs is easy and low cost. Despite all the advantages of PESs, their high vulnerability to natural disasters, frequent switching in harsh environment, and etc. that results in power outages or system shutdown and accordingly increased cost of operating, is one of their biggest disadvantages. Long-term sustainability without power interruption is one of the most important factors in the needs of PESs applications.

In most cases, severe environmental conditions such as high temperatures, over voltage and over current, wear-out of electrical components, radiation, vibration and mechanical damages, thermal damages, hardware design or control defects, and electromagnetic stresses are major causes of critical failures in PESs. Some studies have shown that semiconductors of the primary side (low voltage, high current) and resonance elements used in PESs can be the main sources of damage due to various factors. Faults that occur mainly in different parts of the PESs are divided into two categories of structural faults (hard faults) and parametric faults (soft faults). Each of the hard and soft faults are divided into various types of anomalies.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⋇ Peer-reviewed & Refereed journal ⋇ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

II. LITERATURE REVIEW

A literature survey involves reviewing existing published works, such as academic papers, articles, and books, on a specific topic. It aims to summarize and analyze the existing knowledge in a particular field, identify gaps, and understand the current state of research. Researchers conduct literature surveys to build a foundation for their own work and contribute to the ongoing conversation in their field.

An Overview on the Reliability of Modern Power Electronic Based Power Systems, 2018 Author by JINGYANG FANG, FREDE BLAABJERG paper discusses the reliability aspects of modern power electronic-based power systems. Power electronic devices play a crucial role in various applications, such as renewable energy systems, electric vehicles, and grid-connected systems. These systems often rely on power electronics for conversion, control, and efficient energy management [1].

An Overview on the Reliability of Modern Power Electronic Based Power Systems, 2020Author by SAEED PEYGHAMI, FREDE BLAABJERG paper thoroughly examines the reliability of modern power systems using electronics. It covers assessment methods, challenges, technological advancements, and practical applications. The authors explore failure modes, fault tolerance, and system performance complexities. The paper highlights recent technological progress and its impact on overall system reliability. , the paper provides a detailed analysis of reliability in contemporary power systems reliant on electronics [2].

Survey on Reliability of Power Electronic Systems, 2013Author by YANTAO SONG AND BINGSEN WANG paper explores the reliability of power electronic systems. It may cover aspects such as the reliability of individual electronic components, fault detection and tolerance strategies, common failure modes, testing techniques, and real-world case studies. The paper is likely valuable for researchers and engineers in the power electronics field, providing insights into challenges and advancements in ensuring the reliability of these systems. Accessing the full paper through academic databases or the publisher's website would provide specific details and findings [3].

LSTM Recurrent Neural Network Classifier for High Impedance Fault Detection in Solar PV Integrated Power System, 2021 by VEERAPANDIYAN VEERASAMY, NOOR IZZRI ABDUL WAHAB, This paper presents the detection of High Impedance Fault (HIF) in solar Photovoltaic (PV)integrated power system using recurrent neural network-based Long Short-Term Memory (LSTM) approach. High Impedance Faults can be tricky to detect because they're not as straightforward as low impedance faults. By leveraging LSTM, the researchers are likely taking advantage of the network's ability to remember and learn patterns over longer sequences of data [4].

A Review of the Condition Monitoring of Capacitors in Power Electronic Converters, 2016 Author by Hammam Soliman, Huai Wang, Frede Blaabjerg explores methods to monitor capacitor health in power systems. Capacitors are vital components in these systems, and their condition significantly impacts performance. The authors likely discuss challenges and techniques for monitoring factors like temperature and voltage stress. Effective condition monitoring is crucial for ensuring the reliability and efficiency of power electronic converters. Techniques such as thermal imaging and impedance spectroscopy may be explored. The paper contributes valuable insights into maintaining the optimal functionality of capacitors in power systems [5].

D. Zinchenko, R. Kosenko, D. Vinnikov, and A. Blinov, “Fault tolerant soft- switching current-fed DC-DC converter,” in 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering likely focuses on a current-fed DC-DC converter with fault-tolerant, soft-switching capabilities. The authors likely delve into the design and functionality of this converter, emphasizing its ability to maintain operation even in the presence of faults. The paper could provide insights into applications, benefits, and advancements in soft-switching technologies for enhancing the reliability and robustness of power electronic systems [6].

Q. Sun, Y. Wang, and Y. Jiang, “A Novel Fault Diagnostic Approach for DC-DC Converters Based on CSA-DBN,” IEEE Access likely delves into a new fault diagnostic method for DC-DC converters. The authors might introduce the use of CSA-DBN (Cuckoo Search Algorithm and Deep Belief Network) as an innovative approach. This technique is likely employed to enhance the accuracy and efficiency of diagnosing faults in DC-DC converters. The paper's significance lies in its potential contribution to improving the reliability and performance of power electronic systems by providing a more effective and advanced method for fault diagnosis [7].

W. Jiang, L. Huang, L. Zhang, H. Zhao, L. Wang, and W. Chen, “Control of Active Power Exchange With Auxiliary Power Loop in a Single-Phase Cascaded Multilevel Converter-Based Energy Storage System,” IEEE Transactions on

DOI: 10.17148/IARJSET.2024.114106

Power Electronics. Methodology [1] W. Jiang, L. Huang, L. Zhang, H. Zhao, L. Wang, and W. Chen, "Control of Active Power Exchange With Auxiliary Power Loop in a Single-Phase Cascaded Multilevel Converter-Based Energy Storage System," IEEE Transactions on Power Electronics [8].

J. Popović-Gerber, J. A. Ferreira, and J. D. Van Wyk, "Quantifying the value of power electronics in sustainable electrical energy systems," IEEE Transactions on Power Electronics likely discusses the significance and quantification of power electronics in sustainable energy systems. The authors likely explore the role of power electronics in enhancing the efficiency and sustainability of electrical energy systems. Topics may include the economic and environmental benefits of incorporating power electronics, as well as methods for measuring and assessing their value. This paper could provide valuable insights into how power electronics contribute to achieving sustainability goals in the field of electrical energy [9].

B. Cai et al., "Fault detection and diagnostic method of diesel engine by combining rule-based algorithm and BNs/BPNNs," Journal of Manufacturing Systems employed a methodology that integrates a rule-based algorithm with Bayesian Networks (BNs) and Backpropagation Neural Networks (BPNNs). This approach, detailed in the Journal of Manufacturing Systems aimed to enhance the fault detection and diagnostic capabilities for diesel engines. This techniques can lead to improved accuracy in diagnosing issues within energy, contributing to efficient maintenance and performance optimization [10].

The referenced literature survey focuses on various aspects of power electronic-based power systems. It covers topics such as distributed power system virtual inertia, fault detection in solar PV integrated power system and condition monitoring of capacitors in power converters, reliability of modern power electronic-based systems, design considerations for power electronics in grid-connected photovoltaic systems, and surveys on the reliability of power electronic systems.

Furthermore, some papers introduce novel fault diagnostic approaches for DC-DC converters, explore control strategies for cascaded multilevel converters in energy storage systems, and quantify the value of power electronics in sustainable electrical energy systems. Overall, the research papers contribute valuable insights into enhancing the reliability, fault detection, and control strategies in power electronic systems, spanning applications from renewable energy sources to traditional diesel engines.

III. REQUIREMENT SPECIFICATION

FUNCTIONAL REQUIREMENTS

- Pattern Recognition: Data mining algorithms excel in recognizing patterns within historical energy consumption Data. By analysing past usage patterns, algorithms can identify regularities and co- relations, helping to predict future consumption based on similar condition.

- Forecasting Models: Time series analysis, a common data mining technique, is employed to develop forecasting model for energy consumption. Algorithms analyse temporal patterns seasonality, and tends to generate accurate predictions, aiding in proactive planning and resource management.

- Optimizing Energy Storage: Algorithms assist in optimizing the operation of energy storage systems (ESSs) by predicting energy demands peaks and valleys.

HARDWARE REQUIREMENTS

- Processor: Intel(R) Pentium IV 2.4 GHz.
- System: 64-bit operating system, x64-basedprocessor.
- Ram: 8 GB.
- Network Infrastructure: High-speed and reliable network connections to ensure seamless communication between server components and responsiveness for end-users.
- Hard Disk: 256 GB.

SOFTWARE REQUIREMENTS

- Operating System: Windows 11.
- Language: Python.
- Front-End: Anaconda Navigator-Spyder.

DOI: 10.17148/IARJSET.2024.114106

IV. PROBLEM STATEMENT

Title: Energy Consumption Estimation Objective

The primary objective is to develop a robust forecasting model for predicting baseline electricity consumption, focusing on accurate estimations over a specified period. The scope is defined by excluding variable factors like seasonal fluctuations, holidays, and special events. Key variables, including time series data, weather conditions, day type (weekdays vs. weekends), and economic indicators, form the foundation of the model.

The methodology involves leveraging time series analysis techniques, incorporating machine learning algorithms like ARIMA, LSTM, or Prophet, and integrating external factors for a holistic understanding. Data collection emphasizes gathering high-quality historical electricity consumption data, weather information, and relevant economic indicators from reliable sources to ensure consistency and accuracy in model training. Model evaluation will be conducted using metrics such as MAPE, MSE, and RMSE, with cross-validation to validate reliability.

OJECTIVES

- The central aim of our project is to accurate forecasting that develop a precise model for estimating energy consumption to ensure accurate predictions over specified time periods, facilitating effective resource planning and allocation.
- To achieve this objective, we are dedicated to implementing a diverse set of classification algorithms, seeking to identify the most effective and efficient methods for fault identification.
- This approach not only emphasizes the identification of faults but also underscores the importance of achieving superior performance metrics for the classification algorithms deployed.
- Reliability Validation is implemented to robust evaluation metrics such as Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE), coupled with cross-validation techniques, to validate the reliability and effectiveness of the energy consumption estimation model.

EXPECTED OUTCOMES

- Accuracy and Precision: The primary goal of energy consumption estimation is to achieve accurate and precise results. The expected outcome is a method or model that provides estimates close to the actual energy consumption, reducing the margin of error critical issues.
- Compliance with Regulations: For businesses and industries, an important outcome is compliance with energy efficiency regulations and standards. Accurate estimation can help ensure adherence to legal requirements
- Optimization Opportunities: Accurate energy for consumption estimation enables organizations and individuals to identify areas for optimization. This could involve implementing energy-efficient technologies, adjusting usage patterns, or optimizing processes to reduce overall energy consumption.
- Adaptability and Scalability: Depending on the application, an expected outcome might involve developing estimation models that are adaptable to changing conditions and scalable for different contexts or locations.
- Prediction and Forecasting: Energy consumption estimation often involves predicting future consumption based on historical data. The expected outcome is a reliable model that can effectively forecast energy usage over specific time periods.
- Decision Support: The results of energy consumption estimation can serve as valuable inputs for decision-making. This includes decisions related to infrastructure investments, energy procurement strategies, and sustainability initiatives

V. SYSTEM DESIGN

SYSTEM ARCHITECTURE:

The below figure 5.1 shows the designing a system architecture for electricity consumption estimation involves structuring the various components and modules that work together to fulfil the functional requirements of the project.

Below is a high-level system architecture for an electricity consumption estimation system.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

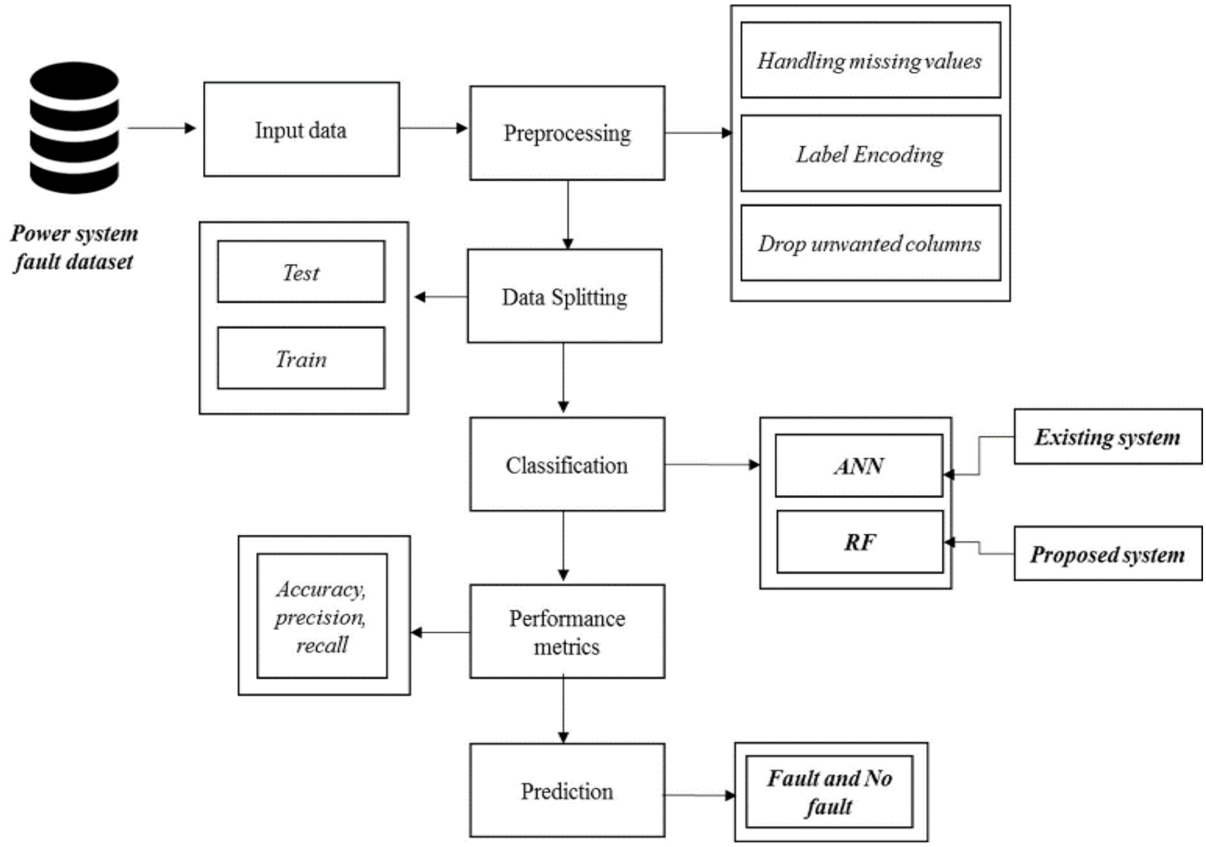

Figure 1: System Design Data

Data Processing and Pre-processing Layer:
Description: This layer cleans and preprocesses the raw data to ensure accuracy and reliability.

Components:
- Data cleaning algorithms.
- Pre-processing modules for handling missing data.
- Time series analysis tools.

Forecasting and Predictive Analytics Layer:
Description: This layer employs forecasting models and predictive analytics to estimate future electricity consumption.

Components:
- Time series forecasting models.
- Machine learning algorithms.
- Predictive analytics engines.

Data Splitting:
Description: Data splitting and components are essential aspects when developing a system for electricity consumption estimation. The process involves breaking down the data into appropriate subsets for training, validation, and testing purposes. Here's how data splitting

Components:
- Machine Learning Models.
- Validation and Hyper parameter Tuning Module.
- Real-time Estimation Engine.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁑ Peer-reviewed & Refereed journal ⁑ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

Performance Metrics:
Description: Performance metrics and components are crucial aspects of an electricity consumption estimation system, ensuring that the models and algorithms used provide accurate and reliable predictions.

Components:
- Feature Importance Analysis.
- Regularization Techniques.
- Real-time Learning Mechanism.

Classification:
Description: There are two types of classifications: ANN (Artificial Neural Network), RF (Random Forest). Artificial Neural Network is Existing System and Random Forest is Proposed System.

Components:
- Testing and Evaluation.
- Real-time Classification Engine.
- Integration with External Data Sources.
- Continuous Monitoring and Maintenance.

ER – DIAGRAM
The below figure 2 shows ER diagram captures the relationships between users, devices, locations, and energy readings. Users can own devices, and each device is associated with energy readings at specific locations. The Energy Reading entity includes information about the energy consumption values recorded at a particular time. By understanding these relationships, it becomes clear how the system manages and organizes data. Users can own devices, devices are linked to specific locations, and energy readings are recorded in association with both devices and locations. This structured representation aids in designing a robust database that can efficiently store and retrieve information about energy consumption within the system. The ER diagram serves as a foundational blueprint for database design, ensuring a logical and organized structure for handling the relationships between users, devices, locations, and energy readings.

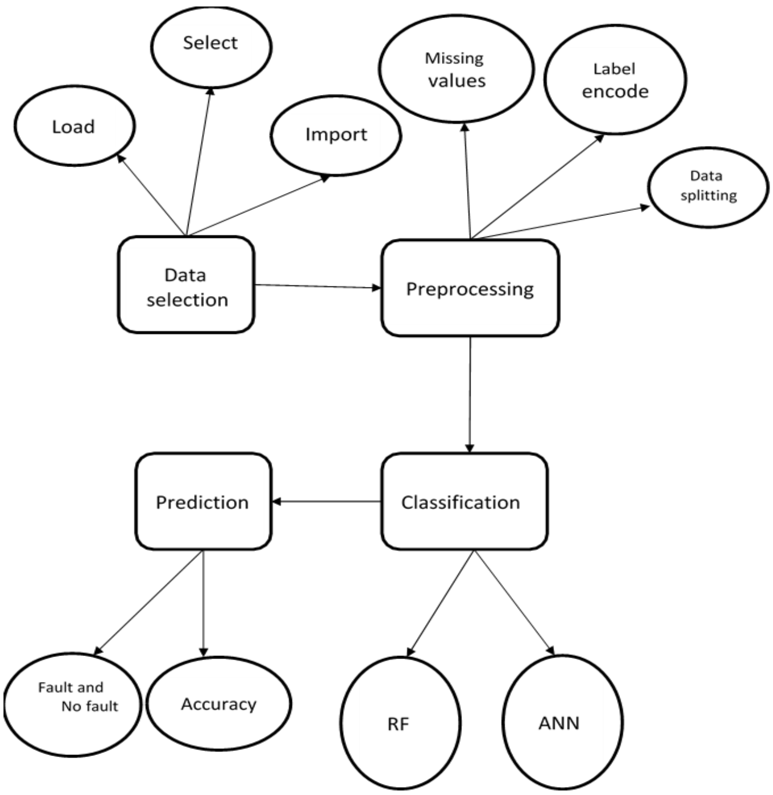

Figure 2: ER Diagram for Energy Consumption

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁒ Peer-reviewed & Refereed journal ⁒ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

VI. RESULT

The result of the Electricity Prediction & Billing project is a user-centric platform that revolutionizes energy management and billing processes. Through the seamless integration of advanced technologies, including machine learning for consumption prediction and secure web development frameworks for user authentication and billing calculation, the system delivers tangible benefits to both users and administrators.

Users gain insights into their energy consumption patterns, enabling them to optimize usage and reduce costs, while administrators benefit from streamlined complaint handling and billing processes. Overall, the project signifies a significant advancement in energy management and customer service within the utility sector, promising benefits for both users and service providers alike.

VII. APPLICATIONS

Forecasting baseline electricity consumption has various applications across different sectors. Here are some key applications:

- Energy Management: Utility companies use baseline electricity consumption forecasts to manage energy generation, distribution, and pricing. Accurate predictions help in optimizing the allocation of resources, reducing operational costs, and ensuring a reliable power supply.
- Grid Planning and Operation: Electricity grid operators rely on consumption forecasts for planning and managing the grid effectively. This includes balancing the load, optimizing the use of renewable energy sources, and ensuring grid stability.
- Infrastructure Planning: Baseline electricity consumption forecasts are crucial for planning new infrastructure, such as power plants, transmission lines, and substations. This ensures that the infrastructure is designed to meet future demand.
- Renewable Energy Integration: With an increasing focus on renewable energy sources, accurate consumption forecasts help integrate renewable energy into the grid by predicting when and how much power will be needed. This aids in balancing the intermittency of renewable sources like solar and wind.
- Demand-Side Management: Businesses and industries use consumption forecasts for demand-side management strategies. This involves optimizing energy use during peak and off-peak hours, implementing energy-efficient technologies, and participating in demand response programs.
- Financial Planning and Budgeting: Accurate forecasts assist businesses and organizations in planning their budgets and managing operational costs associated with electricity consumption.

VIII. ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- High Performance: High performance in forecasting implies that the model can efficiently process data, make to a predictions, and adapt to changes in the environment. High-performing models often exhibit faster computation times, enabling real-time or near-real-time predictions. This advantage is crucial for applications where timely and accurate forecasts are essential, such as energy management or financial markets.
- Accurate Prediction Results: Accurate prediction results are a fundamental advantage of a forecasting model. This means that the model can closely match actual outcomes, providing reliable insights into future trends. Accuracy is particularly important in decision-making processes, as it ensures that stakeholders can trust the forecasts for planning and resource allocation.
- Avoidance of Sparsity Problems: Sparsity problems often arise when dealing with datasets that have a large number of missing or zero values. A forecasting model that effectively avoids or addresses sparsity problems can handle incomplete or irregular data more robustly. This is valuable in real- world scenarios where data may be incomplete or irregularly recorded, ensuring the model's performance is not compromised by missing information.
- Reduction of Information Loss and Bias of Inference Due to Multiple Estimates: When a forecasting model leverages multiple estimates or data sources, it can help reduce information loss and bias in the inference process. By incorporating diverse information, the model gains a more comprehensive understanding of the underlying patterns and trends, leading to more robust and unbiased predictions. This approach is especially beneficial in situations where relying on a single source of information

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⵋ Peer-reviewed & Refereed journal ⵋ Vol. 11, Issue 4, April 2024

DOI: 10.17148/IARJSET.2024.114106

- Faster Training and Inference: Smaller, cleaner datasets generally lead to faster training times for machine learning models. Additionally, when the model is deployed for real-time inference, it can make predictions more quickly. Cleaner datasets accelerate machine learning model training, reducing computational demands and enhancing efficiency.

DISADVANTAGES

- Inefficiency for Handling Large Volume of Data: Forecasting models may face challenges when dealing with large volumes of data. Processing extensive datasets can lead to increased computational demands and longer processing times, potentially affecting the efficiency of the forecasting process. This can be a significant drawback, especially in scenarios where real-time or near-real- time predictions are crucial.
- Theoretical Limits: Forecasting models, by their nature, are based on historical data and patterns. They may struggle to accurately predict outcomes in situations that deviate significantly from historical trends. Unforeseen events, abrupt changes in consumer behavior, or the introduction of new technologies can surpass the model's theoretical limits, leading to less reliable predictions.
- Incorrect Classification Results: If the forecasting model relies on classification algorithms, there's a risk of incorrect classification results. This could lead to misinterpretation of patterns, and the model may assign incorrect labels to data points. Such errors can have cascading effects on subsequent predictions and decision-making processes.

IX. CONCLUSION

In conclusion, an energy consumption estimation machine learning project is a pivotal endeavor with the potential to revolutionize the energy sector. Through the integration of advanced machine learning techniques, the project aims to provide accurate, efficient, and actionable insights into energy consumption patterns. The journey from data collection and preprocessing to model training, validation, and real-time implementation involves a synergy of various components, each playing a crucial role in achieving the project's overarching goals. The adoption of regression and classification models, supported by robust data preprocessing and feature engineering, empowers the system to predict consumption levels and categorize patterns effectively. We conclude that, the power system fault dataset was taken as input. The input dataset was mentioned in our research paper. We are implemented the classification algorithms (i.e) machine and deep learning algorithms. Then, machine learning algorithms such as Random forest and deep learning algorithm such as ANN. Finally, the result shows that the accuracy for above mentioned algorithm and estimated the performances metrics such as accuracy for both algorithms and comparison graph.

REFERENCES

[1] Jing Yang Fang and F. Blaabjerg, “An Overview on the Reliability of Modern Power Electronic Based Power Systems,” IEEE Open Journal of Power Electronics, vol. 1, pp. 34–50, 2018, doi: 10.1109/ojpel.2020.2973926.

[2] S. Peyghami and P. Palensky, “An Overview on the Reliability of Modern Power Electronic Based Power Systems,” IEEE Open Journal of Power Electronics, vol. 1, pp. 34–50, 2020, doi: 10.1109/ojpel.2020.2973926

[3] Y. Song and B. Wang, “Survey on reliability of power electronic systems,” IEEE Transactions on Power Electronics, vol. 28, no. 1, pp. 591–604, 2013, doi: 10.1109/TPEL.2012.2192503.

[4] LSTM Recurrent Neural Network Classifier for High Impedance Fault Detection in Solar PV Integrated Power System, 2021 by Veera Pandiyan Veerasamy and Sanjeevikumar Padmanaban

[5] A Review of the Condition Monitoring of Capacitors in Power Electronic Converters, 2016Author: Hammam Soliman, Huai Wang, Frede Blaabjerg.

[6] D. Zinchenko, R. Kosenko, D. Vinnikov, and A. Blinov, “Faulttolerant soft-switching current-fed DC-DC converter,” in 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering, UKRCON 2019 - Proceedings, 2019, pp. 437–440, doi: 10.1109/UKRCON.2019.8879973.

[7] Q. Sun, Y. Wang, and Y. Jiang, “A Novel Fault Diagnostic Approach for DC-DC Converters Based on CSA-DBN,” IEEE Access, vol. 6, pp. 6273–6285, 2018, doi: 10.1109/ACCESS.2017.2786458.

[8] W. Jiang, L. Huang, L. Zhang, H. Zhao, L. Wang, and W. Chen, “Control of Active Power Exchange With Auxiliary Power Loop in a Single-Phase Cascaded Multilevel Converter-Based Energy Storage System,” IEEE Transactions on Power Electronics, vol. 32, no. 2, pp. 1518–1532, Feb. 2017, doi: 10.1109/TPEL.2016.2543751.

[9] J. Popović-Gerber, J. A. Ferreira, and J. D. Van Wyk, “Quantifying the value of power electronics in sustainable electrical energy systems,” IEEE Transactions on Power Electronics, vol. 26, no. 12, pp. 3534–3544, 2011, doi: 10.1109/TPEL.2011.2166088.

[10] B. Cai et al., “Fault detection and diagnostic method of diesel engine by combining rule-based algorithm and BNs/BPNNs,” Journal of Manufacturing Systems, vol. 57, pp. 148–157, Oct. 2020, doi: 10.1016/j.jmsy.2020.09.001.

