JURNAL UPI

Journal of Mechatronics and Artificial Intelligence

Homepage: http://ejournal.upi.edu/index.php/jmai/

p-ISSN 3062-729X e-ISSN 3048-4227

JMAI JOURNAL OF MECHATRONICS AND ARTIFICIAL INTELLIGENCE

Implementation of Artificial Intelligence in Energy Exploration and Management: A Literature Review

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ARTICLE INFO

Article History:

Submitted/Received 01 Oct 2024
First Revised 01 Nov 2024
Accepted 25 Nov 2024
Publication Date 01 Dec 2024

Keywords:
Artificial Intelligence,
Wind Energy,
Optimalization,
Energy,
Energy Potential

ABSTRACT

This research examines the utilization of artificial intelligence (AI) in the management and exploration of wind energy potential. Three main areas are discussed: 1) Household Energy Management, where AI-based fuzzy logic systems have proven effective in optimizing the use of electrical appliances and reducing energy consumption, 2) Power Generation Energy Management, where artificial neural network (ANN)-based prediction models are capable of accurately estimating fluctuations in electricity demand to enable better supply planning, and 3) Energy Potential Prediction, where AI algorithms such as Backpropagation Neural Network (BPNN) can predict wind speed with a high degree of accuracy, enabling more reliable estimation of the potential for wind power generation. Overall, this research demonstrates that the integration of artificial intelligence technology has great potential in enhancing energy efficiency and management in the future.

1. Introduction

The use of electrical energy is not always linear, as energy needs often fluctuate depending on time, human activity, and environmental conditions [1]. During the day, electricity demand tends to be high due to the large number of industrial activities, offices, and the use of electronic devices [2]. In contrast, at night, energy consumption generally decreases, except in areas with high lighting needs or nighttime activities [3]. This non-linearity is also affected by the season or weather [4]. In summer, electricity use usually increases due to the use of air conditioners [5]. In contrast, in winter, the need for electricity increases for room heating [6]. This variation suggests that electricity consumption patterns are very dynamic and difficult to predict constantly [7].

The use of electrical energy has a direct relationship with the supply of electrical power [8]. The imbalance between energy needs and power supply can have a variety of impacts, both on a small and large scale [9]. When the demand for electrical energy is higher than the power supply capacity, the electrical system can be overloaded, potentially leading to outages or network disruptions [10]. Conversely, if the power provided exceeds the need, the energy generated will be wasted, reducing the overall efficiency of the system [11]. Variations in the use of electrical energy, such as load fluctuations at peak hours and low loads, demand flexible power supply systems [12]. In this case, conventional and renewable power plants must be able to dynamically adjust their output to changes in demand. For example, in renewable energy sources such as wind and solar, power supply is greatly affected by weather conditions that are not always consistent, adding to the challenge of matching supply with demand.

The use of anomalous electrical energy is indeed difficult to predict because of irregular consumption patterns and is often influenced by factors that cannot be predicted in advance. These anomalies can occur as a result of sudden changes in user behavior, technical glitches, or extraordinary events such as natural disasters, major events, or extreme weather changes. Under normal conditions, energy use tends to follow certain daily or seasonal patterns, such as increased consumption during peak hours or during the summer. However, in anomalous situations, this pattern can deviate drastically. For example, electricity use can spike suddenly due to extreme temperature spikes that drive massive use of air conditioning, or it can drop drastically during unexpected large-scale blackouts.

The difficulty in predicting these anomalies is a big challenge for energy system managers, because this uncertainty can disrupt the stability of the power grid and operational efficiency. To overcome this, a monitoring and data analysis system based on advanced technology such as artificial intelligence (AI) is needed [13]. AI can detect anomalous patterns based on historical and real-time data, and provide adaptive responses to manage energy distribution more effectively [14][15]. Thus, although anomalies are difficult to avoid, their impact on the electrical system can be minimized.

Artificial intelligence (AI)-based management is playing an increasingly significant role in modern energy management, especially to address the challenges of efficiency, sustainability, and energy demand uncertainty [16][17]. With the ability to analyze data quickly and in-depth, AI helps optimize energy management from production to consumption. In the context of energy production, AI can predict the output of renewable energy sources such as wind and solar, which are highly dependent on weather conditions. AI algorithms use historical and real-time data to formulate more accurate predictions, allowing operators to optimally manage power production. This is very important to overcome the volatile nature of renewable energy sources.

2. Methods

The research method used in this article is the literature review method. This method is carried out to analyze and summarize various studies that are relevant to the topic of the use of Artificial Intelligence (AI) in energy management and exploration, especially those related to wind energy. The following are details of the steps taken in the selection process and analysis of the journals used.

The research began by identifying 100 journals from various scientific sources, including large databases such as Scopus, IEEE Xplore, and ScienceDirect. These journals were selected based on keywords related to the research topic, such as:

- "Artificial Intelligence in Energy Management"
- "Wind Energy Potential Prediction"
- "Smart Energy Management"

This selection aims to obtain comprehensive references on the application of AI in energy management and prediction of wind energy potential. After collecting relevant journals, the next step is the first screening by evaluating the abstract and keywords of each journal. This process aims to ensure the suitability of the journal topic with the research objectives. Journals that are not relevant or do not meet the quality criteria (such as low citations or less valid methodologies) are removed. The result of this screening is 20 journals that are more focused and more in-depth.

At this stage, a more in-depth analysis is carried out on the complete contents of the journals that have been filtered in the first stage. The things analyzed include:

- Methodology used in the research,
- Research results obtained,
- Discussion relevant to the application of AI in energy management and prediction of wind energy potential.

Researchers ensure that the selected journals have strong data and analysis, high relevance to the topic discussed, and significant contributions to understanding the role of AI in energy management. From the results of the second screening, 10 journals were obtained that were considered the most relevant and of high quality. These journals were then used as a basis for formulating conclusions and broader research findings regarding the application of AI in energy management.

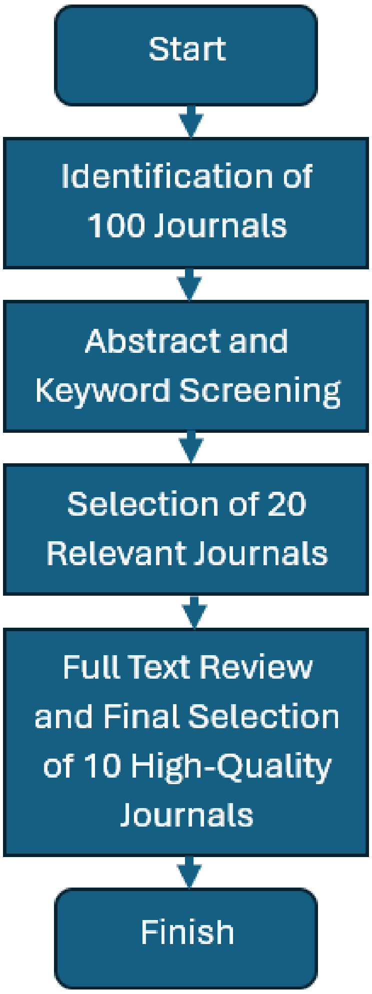

Figure 1. Research Flowchart

3. Results and Discussion

3.1. *Home Energy Management*

This research by Afandi, et al (2024) focuses on the use of artificial intelligence (AI) technology based on fuzzy logic control for energy management in smart homes [18]. AI-based home energy management: This sentence explains the main topic of the study, which is the use of AI technology to manage energy usage at home. The use of AI here allows for smarter and more efficient energy management, optimizing electricity usage according to the needs and conditions of the home.

Advances in digital technology and smart homes: This study links the development of digital technology with the advancement of the smart home concept. A smart home is a home that uses technology to improve comfort and efficiency, such as automatic control of household appliances, lighting, heating, cooling, and more. This study shows that more and more people are interested in smart homes as a solution to improve their quality of life. Challenges in developing smart homes -

optimizing electricity usage: One of the biggest challenges in developing smart homes is managing energy usage, because many electronic devices are used simultaneously, which can lead to energy waste.

Application of AI-based fuzzy logic control: This study utilizes the fuzzy logic control approach as one of the AI methods to overcome uncertainty or ambiguity in decision making. Fuzzy logic is used to manage energy usage by considering uncertain factors, such as room temperature, available power from solar panels, and battery voltage levels. This allows for more efficient energy adjustments, for example, by adjusting the fan speed or the duration of washing machine use.

Principle of fuzzy logic: Fuzzy logic is an approach in AI that is similar to the way humans make decisions in uncertain or ambiguous situations. For example, humans do not always make decisions based on definite data (such as the exact temperature of 20°C), but rather on more flexible and "fuzzy" judgments (such as "cold enough" or "hot enough"). Reduction in energy consumption: The implementation of this technology in a smart home prototype has succeeded in reducing energy consumption by up to 278.9 watts/hour compared to conventional methods. This shows that the application of fuzzy logic-based AI can significantly improve the efficiency of energy use.

The benefits of AI in energy management: The findings of this study show that AI has great potential in improving energy efficiency, in a more adaptive and responsive manner to changing conditions. This can reduce household operating costs, which in turn helps reduce the environmental impact of energy consumption. Further development: This study also opens up opportunities for further research, especially in the development of additional features that can further improve the efficiency and comfort of smart homes in the future. This leads to the possibility of wider applications of AI in home energy management and smart home technology as a whole.

3.2. *Power Plant Energy Management*

Energy management using AI is also used in power plants, especially wind power. The research was conducted by Arungpadang et al (2018), the research aimed to predict the demand for electrical energy in North Sulawesi Province, Indonesia using the artificial neural network (ANN) method [19]. This study explains the use of artificial intelligence (AI) in energy management, especially in power plants that utilize wind energy and, in this case, focuses on modeling electricity demand in North Sulawesi Province, Indonesia.

This research aims at the application of AI in energy management in power plants, with a particular focus on wind energy. Wind energy has great potential, especially for areas with stable wind speeds, and this research examines how AI can help plan and manage energy supply from wind power plants more efficiently. The increasing demand for electricity along with economic development: This research shows that the demand for electricity is increasing, along with economic growth which leads to more energy consumption. Therefore, proper planning is needed to ensure that electricity supply can match the increasing demand.

Use of historical data to train ANN model: In this study, historical data on electricity demand is used to train an ANN (Artificial Neural Network) model to predict future electricity demand. This historical data includes records of past energy usage that are used to analyze energy consumption patterns and predict how energy demand will change. Training process of ANN model using Levenberg-Marquardt algorithm: Training of ANN model is done using Levenberg-Marquardt algorithm, which is an efficient optimization algorithm for training artificial neural networks. This algorithm helps to find the most appropriate weights and parameters so that the ANN model can make accurate predictions based on the given data.

Gap analysis between installed generating capacity and predicted energy demand: This study also includes a gap analysis between installed generating capacity and predicted electricity demand. This gap analysis is important to assess whether the existing generating capacity is sufficient to meet the predicted demand or whether there is a capacity shortage that needs to be considered in energy supply planning. Research findings – ANN model can capture fluctuation patterns in electricity demand: One of the main findings of this study is that the ANN model can identify fluctuation patterns in electricity demand, which are more complex and dynamic, while other methods such as exponential smoothing only provide simpler linear trends. ANN is better at predicting changing and irregular demand patterns. Comparison of ANN performance with exponential smoothing method: The ANN model is proven to be more effective than the exponential smoothing method in terms of energy demand prediction accuracy. This shows that ANN is better able to reflect the dynamics of energy demand that does not always follow a pattern that is easily predicted linearly. Gap analysis between generating capacity and demand shows that the generating capacity is still higher than the predicted demand: The gap analysis shows that the installed generating capacity in the area is still higher than the predicted energy demand. This means that the energy supply in the area is sufficient to meet energy needs, as long as the power generation and distribution systems are operating properly and are maintained.

The ANN approach is effective in modeling and predicting energy demand: Overall, this study shows that the ANN approach is very effective in modeling and predicting electricity demand in North

Sulawesi Province. This shows the potential use of AI in planning and managing future energy demand. The analysis of the gap between generating capacity and predicted demand also provides valuable insights into energy supply planning in the area, allowing authorities to make adjustments in the construction and management of power plants to match the estimated needs.

3.3. *Energy Potential Prediction*

Research on energy potential prediction was conducted by Malek et al (2023). In the study, it was explained that this research focuses on predicting medium-term wind speed using Artificial Neural Network (ANN) to estimate the potential of wind power in Sabang City, Aceh [20]. Indonesia, as an equatorial country, has great renewable energy potential, one of which is wind energy. Along with economic growth and population growth, the need for electricity in Indonesia, especially in Aceh, continues to increase. Therefore, it is important to build environmentally friendly and financially efficient power plants, one of which is a wind power plant (PLTB).

The availability of wind at a certain speed is expected to support the construction of PLTB. However, to realize this, accurate wind speed prediction data is needed. Wind speed itself is a random variable that is difficult to predict accurately, so research like this is needed to improve prediction accuracy. In this study, the Backpropagation Neural Network (BPNN) algorithm was used, which is one type of algorithm in the Artificial Neural Network (ANN), to predict wind speed in Sabang. The BPNN algorithm was chosen because of its ability to identify non-linear relationships and its ability to adapt to changes in data that occur. Meteorological data, such as wind speed, temperature, air pressure, and humidity, were collected from BMKG (Meteorology, Climatology, and Geophysics Agency) as input for the prediction model.

The results of this study indicate that the BPNN algorithm is able to predict wind speed in Sabang with a very low error rate, which is only 0.0036. With this accurate wind speed prediction, the potential for electrical energy that can be generated by the PLTB in Sabang can be estimated. For example, in July 2021, the estimated electrical energy production from the PLTB in Sabang was 81.5 KWH. This study shows that Sabang City has good potential for PLTB development, and the BPNN algorithm has proven to be an effective method for predicting wind speed. These findings provide important references and considerations in planning the development of wind power plants in Sabang, which can later help ensure energy sustainability in the area and support more efficient and environmentally friendly renewable energy planning.

4. Conclusion

In the context of household energy management, AI-based fuzzy logic systems have proven effective in optimizing the use of electrical appliances and reducing energy consumption. On the other hand, at the power generation level, artificial neural network (ANN)-based prediction models are capable of accurately estimating fluctuations in electricity demand, assisting in better supply planning. In terms of exploring wind energy potential, AI algorithms such as Backpropagation Neural Network (BPNN) can predict wind speed with a high degree of accuracy, enabling more reliable estimation of the potential for wind power generation.

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