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Microgrid Energy Management using Weather Forecasts: Case Study, Discussion and Challenges

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ABSTRACT

The main objective of this study is to demonstrate the integration of weather forecasts which can lead to a significant reduction in energy costs and carbon emissions while ensuring the reliability of the microgrid operation. By serving a small area or a particular building, the incorporation of weather forecasts can considerably increase the efficiency of microgrid energy management. The planning and operation of microgrids can be greatly improved by using weather predictions, which give useful information about upcoming weather conditions. By forecasting future energy demand and supply based on meteorological conditions, Microgrid Energy Management (MEM) is utilized to optimize the energy management decisions in microgrid systems. Making better choices regarding energy generation, storage, and consumption may be aided by the incorporation of weather forecasts, which can offer a more precise and trustworthy estimate of the energy demand and supply. This strategy can result in increased energy efficiency, decreased energy prices, and decreased carbon emissions, all of which are important goals for contemporary power systems. A promising approach for raising energy effectiveness and lowering greenhouse gas emissions in contemporary power networks is MEM. The incorporation of weather forecasts into MEM can improve decision-making regarding energy management by giving a better insight of future energy demand and supply. This essay examines the advantages and disadvantages of using weather forecasts in MEM through the presentation of a case example. By providing valuable information about future weather conditions, weather forecasts this review explain the Optimized Renewable Energy Integration, Improved Energy Storage Utilization, Load Shifting and Demand Response, Efficient Grid Management for reducing reliance on fossil fuels and lowering energy cost and carbon emissions. In order to address the issues related with MEM employing weather forecasts, this study offers potential fixes for increasing the accuracy of weather forecasts and emphasizes the necessity for more research in this area.

1. Introduction

A microgrid (MG) is envisioned as a small-scale power system [1] made up of a variety of loads and distributed energy sources, such as solar panels, wind turbines, conventional generators, and energy storage systems. MGs have shown to be effective at reducing the effects of the intermittent generation [2] linked to renewable energy sources (RES) and can operate in both grid-connected and stand-alone modes [3]. As a result, they are seen as essential components for promoting the integration of RES into the power system and the accompanying decrease in the amount of environmental pollutants caused by conventional energy sources. The local nature of the problem in the case of MGs amplifies uncertainty, which has an effect on RES and load calculations in particular. In this way, Olivares et al. linked the dispatch and schedule of units under variable supply and demand to the first major technical issue in MG control.

The use of weather forecasts in microgrid energy management is a promising strategy for improving the performance of tiny power systems that are connected to the main grid. The standard centralized grid is often connected to and synchronized with a limited collection of electrical sources and loads called a microgrid. But, depending on the economic and/or environmental circumstances, the microgrid may be disconnected and operate independently. Operators can estimate the renewable energy sources that will be available by integrating weather forecasts into microgrid management [4], which can assist maximize the usage of renewable resources, lower energy costs, and cut carbon emissions.

The integration of weather forecasts with the energy management system (EMS) of a microgrid on a university campus serves as the case study for this methodology [5]. Solar panels, battery storage, and a standby diesel generator make up the campus microgrid. The weather forecast data is used by the EMS to forecast the solar energy that will be available, which is then used to optimize the operation of the microgrid. To make the most of renewable energy sources and cut down on energy expenses, the EMS also analyzes weather forecast data to decide when to charge and discharge the battery storage.

Integrating weather forecast data with the energy management system of a microgrid involves several steps and considerations. The process requires reliable data sources, communication infrastructure, and advanced control algorithms. Weather forecast data can be effectively integrated into the energy management system by Selecting Reliable Weather Data Source, Data Collection and Communication, Data Pre-processing and Quality Control, integrate with Energy Management Software, Renewable Energy Forecasting, Load Forecasting, Energy Storage Optimization, Demand Response Management, Monitoring and Validation. By following these steps and effectively integrating weather forecast data into the energy management system, microgrid operators can optimize energy usage, reduce costs, enhance grid stability, and minimize carbon emissions, making their microgrid systems more efficient, reliable, and sustainable.

The reliability of weather forecasts presents the biggest obstacle to putting this strategy into practice [6]. Even the most accurate weather forecasts can make mistakes because weather is fundamentally unpredictable. For microgrid operations, the accuracy of weather forecasts is particularly important [7] because faulty forecasts can result in the wasteful use of energy resources and higher expenditures. Microgrid operators can overcome this difficulty by employing ensemble forecasting, which entails making many forecasts and averaging the results to increase accuracy.

Another challenge is the integration of weather forecast data with the EMS [8]. The EMS must have access to and be able to incorporate real-time meteorological data into the operation of the microgrid. This requires the use of specialist software and hardware that can interface with weather forecasting systems in order to complete the task and incorporate the data into the EMS.

A promising strategy to improve the performance of small-scale power systems is microgrid energy management utilizing weather forecasts [9]. The case study demonstrates the advantages of this strategy and the issues that must be resolved for it to be successfully implemented. This strategy is probably going to be used more and more in the energy sector as weather forecasting technology advances and microgrid management systems advance.

The use of weather forecasts in microgrid energy management is a promising strategy for improving the performance of tiny power systems that are connected to the main grid [10]. Using renewable energy sources to the fullest potential, cutting energy costs, and lowering carbon emissions are all possible with this strategy. To properly adopt this strategy, there are various issues that must be resolved.

Accuracy of weather forecasts is one of the major issues [11]. Even the most accurate weather forecasts can make mistakes because weather is fundamentally unpredictable. If the forecasts are off, this could result in an inefficient use of energy resources and higher expenses. Microgrid operators can overcome this difficulty by employing ensemble forecasting, which entails making many forecasts and averaging the results to increase accuracy.

The integration of weather forecast data with the microgrid's energy management system (EMS) presents another difficulty. Real-time weather information must be able to be accessed by the EMS [12] and integrated into the microgrid's functioning. In order to accomplish this and incorporate the data into the EMS, specialized software and hardware must be able to interface with weather forecasting systems. Notwithstanding these difficulties, case studies of Microgrid Energy Management Using Weather Predictions have been effective.

This review paper can provide a comprehensive overview of the current state-of-the-art in microgrid energy management using weather forecasts. This can help researchers and practitioners to understand the existing techniques and their limitations, as well as identify areas where further research is needed. This article uses weather forecasts to assess the potential and challenges related to microgrid energy management. For instance, the paper could examine the difficulties of reliable weather forecasting and the advantages of developing renewable energy technologies. This review paper can offer suggestions for future studies in the area of weather-based microgrid energy management. This can involve recognizing knowledge gaps and proposing fresh lines of inquiry into significant problems and chances.

Future academics and society will benefit greatly from the incorporation of weather forecasts into microgrid energy management thanks to its enhanced use of renewable energy sources, lower costs, and decrease of carbon emissions. To ensure efficient and sustainable microgrid energy management utilizing weather forecasts, however, issues with forecast accuracy, real-time adaption, data integration, and regulatory restrictions need to be solved. The promotion of efficient and sustainable energy systems at the local level can be greatly aided by microgrids if these difficulties can be overcome.

2. Method

In this case study, we describe a methodology for microgrid energy management in a small-scale microgrid servicing a university campus that makes use of weather forecasts. The microgrid includes an energy storage system in addition to renewable energy resources like solar PV panels and wind turbines. Through efficient energy management supported by reliable weather forecasts, the goal is to maximize energy utilization, save expenses, and reduce carbon emissions. Acquiring current weather forecast data from reliable sources is the first stage. Accuracy and dependability are ensured by pre-processing and quality control tests. We can accurately forecast the production of renewable energy by using the weather forecast data to predict solar irradiance and wind speed. In order to improve load forecasting, we combine the forecasts with historical load data and estimate future energy consumption based on weather-dependent variables like temperature and humidity.

We make the energy storage system run as efficiently as possible using renewable energy and load forecasts. In order to improve efficiency and grid stability, the battery storage is charged during times of high renewable energy generation and discharged during times of peak demand. In addition, we combine weather forecast data into demand response programs, activating demand response during severe weather to limit energy consumption in non-essential sectors and guarantee enough energy supply to key loads. The microgrid can adapt energy generation and consumption in response to shifting weather conditions thanks to the use of real-time control algorithms, ensuring the best possible use of the available energy resources. Due to the microgrid's integration with the main grid, trading in electricity is made possible. We optimize energy trading tactics and contribute to grid stability by using weather forecast data to drive our judgments about energy trading and market participation.

The reliability of the microgrid is increased by resilience planning based on weather forecasts, which provides readiness for adverse weather occurrences. To ensure the effectiveness of the methodology, issues such prediction accuracy, real-time adaption, data integration, and regulatory hurdles are addressed. Utilizing weather forecasts as part of the microgrid energy management approach enables the microgrid to maximize the use of renewable energy, save costs, and improve grid stability. Data-driven decisions are influenced by the integration of weather forecast data, resulting in an energy system that is resilient, cost-effective, and sustainable for the demands of the university campus.

The success of microgrid energy management and the integration of renewable energy sources is directly influenced by the accuracy of weather forecasting models and the effects of weather variability on energy production. Weather forecasting models are numerical simulations that project future weather conditions based on atmospheric and environmental data. The caliber and volume of input data affect how accurate weather forecasts are. Predictions are more accurate when they are based on high-quality observational data, satellite images, and weather station readings. The effectiveness of renewable energy sources and, subsequently, energy generation in microgrid systems, for instance, are directly impacted by weather unpredictability. Cloud cover, atmospheric conditions, and seasonal changes can all affect sun irradiance, which can affect solar PV panels. The amount of solar energy produced can be greatly reduced by cloud cover, affecting energy production. Wind turbines are dependent on wind direction and speed. The constancy of energy production from wind resources is impacted by wind variability, including lulls and gusts.

The ability to schedule renewable energy sources and energy storage systems efficiently depends on the accuracy of weather forecasting models, which is essential for microgrid energy management. Climate change has a direct impact on the generation of energy from renewable sources, which can provide problems for the management of the grid and the supply of energy. Microgrid operators must use cutting-edge forecasting models, put effective energy management techniques into practice, and prepare for grid resilience during extreme weather events in order to lessen the effects of weather variability. Furthermore, improvements in weather forecasting technology and data assimilation methods can increase the precision of weather predictions, enhancing the overall effectiveness and dependability of microgrid energy systems.

3. Wind Energy Generation

A good strategy to maximize the usage of renewable energy sources is to use weather forecasts to predict wind energy generation in a microgrid [13]. Wind is the most globally used ambient source of harvesting large scale power to mitigate the power crisis for large scale electronics devices. Wind energy harvesting system has been shown in Fig. 1. The functioning of the microgrid can be planned in accordance with the estimated amount of electricity that wind turbines can produce by anticipating the wind speed and direction. This could lessen the microgrid's dependency on non-renewable energy sources and increase its sustainability.

There are numerous ways to predict the amount of wind energy produced by a microgrid. Using numerical weather prediction (NWP) models [14], which simulate atmospheric conditions and forecast wind speed and direction for a specific place, is one popular strategy. Another strategy is to utilize machine learning algorithms to discover from historical data the patterns and connections between meteorological variables and wind energy generation [15].

When wind energy production is anticipated, the operation of the microgrid can be optimized [16]. For instance, the microgrid can prioritize using renewable energy sources and store extra energy in batteries for later use if the forecast predicts significant wind energy generation. On the other side, the microgrid can rely more on other energy sources or adapt its energy consumption to meet the available energy supply if the forecast predicts low wind energy generation [17]. Overall, optimizing the utilization of renewable energy sources and increasing the sustainability of the microgrid can be accomplished by using weather forecasts to estimate wind energy generation in the microgrid.

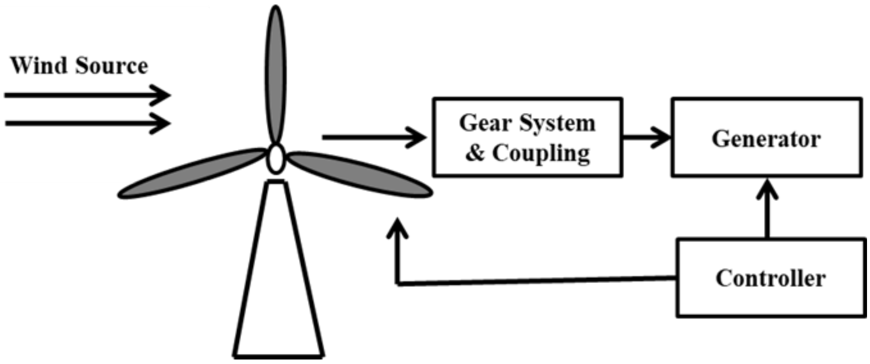

Fig. 1. Wind energy generation system

The following are a few ways to generate wind power in a microgrid using weather forecasts:

1. Wind turbines: In a microgrid, wind energy is most frequently produced via wind turbines. Weather information can be used to forecast the wind speed and direction, which determine how much power is produced by wind turbines [18].
2. Models for predicting wind direction and speed at a specific place include numerical weather prediction (NWP) models, which simulate atmospheric conditions [19]. Using historical data, machine learning algorithms can also be utilized to discover patterns and connections between meteorological factors and wind energy production.
3. Wind turbine micro-siting: To maximize the quantity of wind energy produced, wind turbines are strategically positioned within the microgrid. The ideal positions for the turbines can be found using weather forecast data [20].
4. With battery storage systems, extra wind energy produced during times of high wind speed can be stored and utilized during times of low wind speed. Weather forecast information can be used to calculate the ideal quantity of energy to store in the batteries.
5. Microgrid control systems: Based on weather forecast information, microgrid control systems can be utilized to maximize the usage of wind energy in a microgrid. These systems can prioritize the usage of renewable energy sources based on the weather forecast, automatically modify the energy demand, and store excess energy in batteries [21].

In general, these techniques for producing wind energy in a microgrid using weather forecasts can aid in maximizing the use of renewable energy sources, lowering reliance on non-renewable energy sources, and improving the sustainability and efficiency of the microgrid.

4. Solar Energy Generation

An effective method for maximizing the usage of renewable energy sources is to use weather forecasts to predict solar energy generation in a microgrid. By estimating the quantity of sunlight that will be accessible, it is feasible to plan the microgrid operation and predict the amount of energy that can be generated by solar panels. This could lessen the microgrid's dependency on non-renewable energy sources and increase its sustainability. For generating solar energy, a solar system needs to be formed by using solar panel, charge controller and battery. Solar system can harvest pure energy from the sun. That is why solar energy has been a great concern for home appliances. Solar energy harvesting system using pulse width modulation (PWM) and Maximum power point tracking (MPPT) control has been shown in Fig. 2.

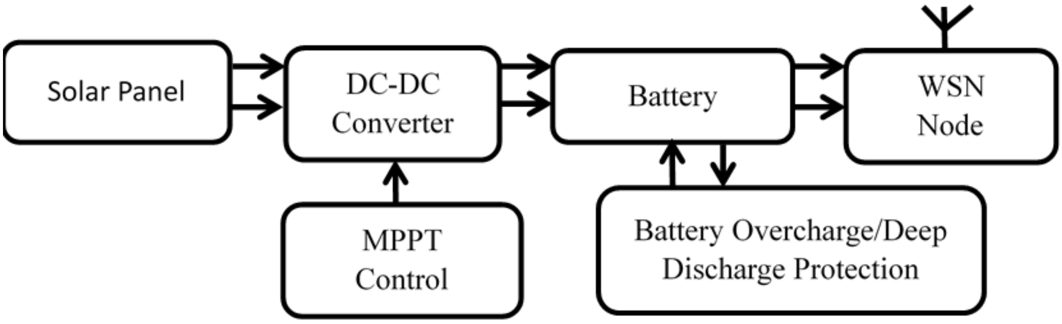

Fig. 2. Block diagram of solar energy harvesting system using PWM and MPPT control

Forecasting solar energy generation in a microgrid can be done in a number of ways. Numerical weather prediction (NWP) models [22], which mimic atmospheric conditions and forecast the amount of solar radiation that will reach a specific area, are one popular method. Another strategy is to utilize machine learning algorithms to discover from historical data the patterns and connections between meteorological variables and solar energy production.

When solar energy production is anticipated, the microgrid operation can be optimized [23]. For instance, the microgrid can prioritize using renewable energy sources and store extra energy in batteries for later use if the forecast predicts significant solar energy generation. On the other side, the microgrid can rely more on other energy sources or adapt its energy consumption to meet the available energy supply if the forecast predicts low solar energy generation.

Overall, predicting solar energy generation in a microgrid based on weather forecasts can be a good strategy to maximize the utilization of renewable energy sources [24] and increase the sustainability of the microgrid. By better balancing energy supply and demand, it can also help to lower overall energy costs and increase the reliability of the microgrid.

There are various ways to generate solar power in a microgrid utilizing weather predictions, including:

1. PV (photovoltaic) panels: PV panels use sunshine to produce electricity. PV panel output is based on the amount of sunshine received, which may be predicted using weather information [25].
2. Using mirrors or lenses, concentrated solar power (CSP) devices focus sunlight onto a tiny area, heating a fluid that powers a turbine to produce electricity. The amount of power produced by CSP systems is also influenced by sunshine intensity [26], which can be predicted using weather information.
3. Solar tracking systems: To maximize the amount of sunlight that solar panels get, solar tracking systems employ sensors to detect the sun's movement and change the angle at which the panels are oriented [27]. Based on weather forecast information, these technologies can be utilized to maximize the usage of solar energy.
4. Systems for storing batteries: Systems for storing batteries can be used to store extra solar energy [28] produced during times of intense sunlight and use it during times of low sunlight. Weather forecast information can be used to calculate the ideal quantity of energy to store in the batteries.
5. Control systems for microgrids: Based on information from weather forecasts, control systems for microgrids can be used to optimize the usage of solar energy in a microgrid. Based on the weather forecast, these systems can prioritize the use of renewable energy sources and alter the energy demand automatically. They can also store excess energy in batteries [29].

In general, these techniques for solar energy generation in a microgrid utilizing weather forecasts can aid in maximizing the use of renewable energy sources, reducing dependency on non-renewable energy sources, and making the microgrid more cost-effective and sustainable.

Load is dependent on other factors associated to specific MG patterns, such as building occupancy, seasonality, or consumer behavior, in contrast to RES generation, which is largely driven by the weather. As a result, weather forecasts for load prediction are treated even more ancillary in MG literature. In [30], load predictions were made by an ANN that analyzed 48 hours of load measurements and 24 hours of weather service temperature forecasts. The approach is similar in [31], except it processes temperature projections for 36 hours in advance as well as 36 hours of load observations. Two weather forecast services' data on outdoor temperature and global irradiance were employed in [32], with a key emphasis on thermal loads.

Load forecasting for district energy management was researched on a bigger scale in [33]. The investigations mentioned above supported the idea that load is influenced by the weather. The most important weather parameter appears to be the external temperature, while the loads for ventilation, heating, and cooling appear to be more weather-dependent. However, as was already mentioned, most MG studies do not take weather data into account when predicting load.

5. Artificial Neural Network

The computerization of human abilities serves as the foundation for ANNs, a type of artificial intelligence. Standard computer processing takes place in a fundamentally different way from how the human brain works, which must be taken into account. The human brain can execute some tasks better than even the most sophisticated conventional computers, such as pattern recognition and vision, because of its complex, nonlinear, and parallel working [34]. Artificial intelligence has improved computer capabilities by modeling the biological information-processing system of humans. Since ANNs may imitate the biological neural network seen in the human brain, they are very adept at recognizing patterns and predicting future values.

An artificial neural network (ANN), a method for machine learning, is based on how the human brain functions and is organized. It is composed of a network of weighted nodes, also known as synthetic neurons, that are stacked in layers and connected shown in Fig. 3. The input layer receives input data, processes it at the hidden levels, and then sends it to the output layer, which produces the output in the end. During training, the weights of the connections between the nodes are changed to enhance the performance of the network. ANNs are frequently used in applications such as audio and picture recognition, natural language processing, and predictive modeling [35].

Among other techniques, they can be trained using supervised learning, unsupervised learning, and reinforcement learning. Convolutional neural networks, recurrent neural networks, and feedforward neural networks are only a few of the several types of ANNs. Each category is suitable for different tasks and data types. ANNs are a popular topic in the artificial intelligence community and have shown to be powerful solutions for solving challenging issues.

There are several advantages of artificial neural networks (ANNs), which include:

1. Non-linearity: ANNs are especially helpful in applications where the relationship between variables is difficult to quantify since they can simulate complicated non-linear interactions between inputs and outputs [37].
2. Robustness: Even with noisy or inadequate data, ANNs are capable of making accurate predictions or classifications [38].
3. Adaptability: Without making substantial modifications to the model structure or technique, ANNs can adjust to changes in the input data or the problem being solved [39].
4. Parallel processing: Due to their parallel computing capabilities, ANNs are ideal for applications needing real-time processing or extensive data analysis [40].
5. Fault tolerance: Even when part of the connections or nodes fail, ANNs may still make precise predictions [41].

6. Feature extraction: The requirement for human feature engineering is decreased by the ability of ANNs to automatically extract pertinent features from the input data.
7. Generalization: ANNs are effective in applications like pattern recognition, picture and speech processing, and natural language processing because they generalize well to new, unseen data.

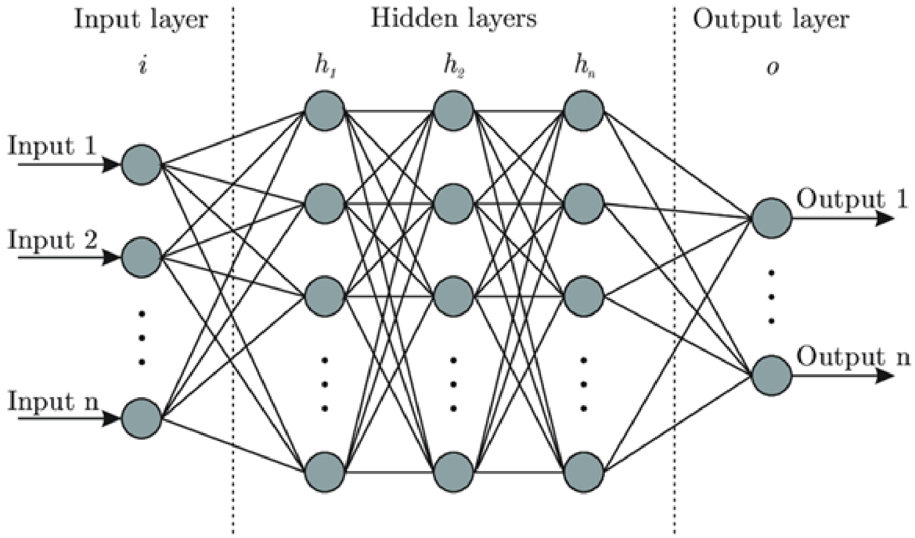

Fig. 3. Artificial Neural Network [36]

Overall, ANNs are powerful machine learning tools that can be used to solve a wide range of problems in different fields, including finance, healthcare, engineering, and many others.

Artificial neural networks (ANNs) are able to forecast energy production by examining the relationship between input variables like the weather and the output variable, energy generation. The historical data that is utilized to train ANNs includes the input variables solar irradiance, temperature, humidity, wind speed, cloud cover, as well as the associated energy generation values. An Artificial neural network (ANN) architecture has been shown in Fig. 4.

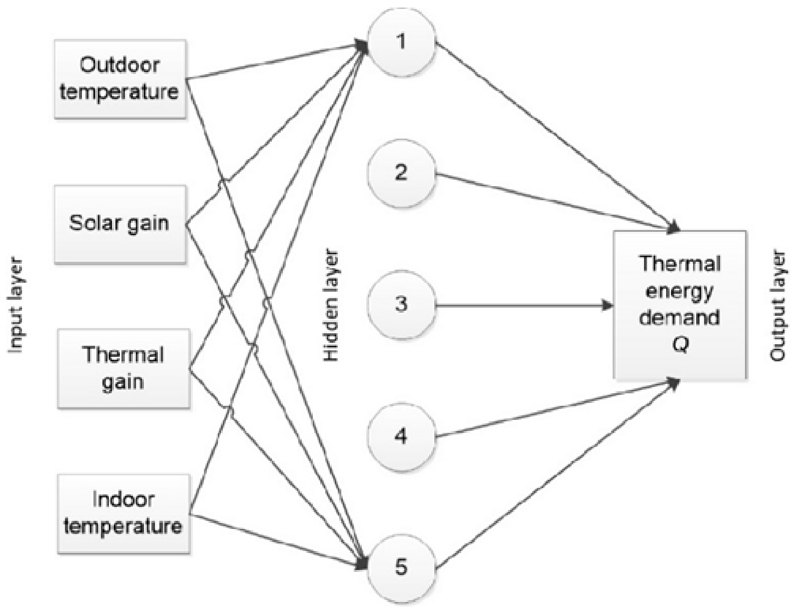

Fig. 4. Artificial neural network (ANN) architecture of building prediction model [42]

During the training phase, ANNs adjust their weights and biases to minimize the discrepancy between the expected and actual output [43]. In this procedure, the input variables are processed through the layers of the neural network before computing the anticipated result. Following a comparison of the expected output and the actual output, the weights and biases of the neural network are modified using backpropagation.

The neural network can be used to forecast energy generation for new input variables, such as upcoming weather conditions, after it has been trained. The trained neural network receives the input variables as input and processes them to calculate the anticipated output of energy generation.

How correctly the neural network predicts energy generation depends on a number of factors, including the quality of the training data, the complexity of the neural network design, and the accessibility and accuracy of the input variables [44]. Yet, in order to increase energy output and reduce costs, ANNs are commonly used in renewable energy systems. They have shown promising outcomes when predicting energy production.

6. Artificial Neural Networks Model

To predict solar energy generation using artificial neural networks, we can follow these general steps:

1. Data collection: Collect data related to solar energy production, such as historical solar irradiance data, temperature data, humidity data, and historical solar energy production data [45].
2. Data pre-processing: Clean and pre-process the collected data. This includes handling missing data, scaling the data, and splitting it into training, validation, and testing sets [46].
3. Model selection: Choose the appropriate type of artificial neural network that best fits the problem. For solar energy generation prediction, a feedforward neural network or a recurrent neural network might be appropriate.
4. Model architecture design: Determine the number of input features, hidden layers, and number of neurons per layer for the selected neural network model [47].
5. Model training: Train the neural network model using the preprocessed training data. This involves adjusting the weights and biases of the neural network to minimize the prediction error.
6. Model validation: Use the preprocessed validation data to evaluate the performance of the trained neural network model. This helps to identify if the model is overfitting or under fitting the data.
7. Model testing: Use the preprocessed testing data to evaluate the final performance of the neural network model.
8. Model deployment: Deploy the trained neural network model to predict solar energy generation for future periods. This involves using the trained model to predict solar energy generation based on new data, such as solar irradiance, temperature, and humidity data.
9. Model monitoring and improvement: Continuously monitor the performance of the deployed neural network model and update the model as necessary to improve its accuracy and reliability [48].

7. Methodology

The following is a methodology for solar energy generation through artificial neural network using weather forecast for microgrid:

1. Collect weather data: Get weather information from a variety of places, such as the meteorological office or weather websites. Climate-related factors including precipitation, wind speed, humidity, and sun irradiance should all be included in the data.

2. Gather solar data: Assemble solar data from the microgrid's solar panels. Variables like solar panel capacity, efficiency, and orientation should be included in the data.
3. Develop artificial neural network: Create an artificial neural network (ANN) model that uses weather data to forecast the production of solar energy. For the ANN to successfully forecast future solar energy generation, historical weather and solar data should be used as training data.
4. Test and validate ANN model: Using current meteorological information and data on solar energy production, test and validate the ANN model. Based on the weather forecast, the model ought to be able to estimate solar power generation with accuracy.
5. Integrate the ANN model into the microgrid: By incorporating the ANN model into the microgrid system, solar power generation may be adjusted automatically based on the weather forecast. By doing this, the microgrid will be able to optimize the amount of solar electricity it generates while minimizing any unnecessary energy output.
6. Monitor and optimize the microgrid: To make sure the microgrid system is running well, monitor and improve it. The ANN model can be regularly updated to reflect the most recent information on the weather and solar power generation.

Ultimately, this technology makes it possible for a microgrid system to deploy solar power generation more effectively and efficiently by making use of the capabilities of artificial neural networks and weather forecast data. With the aid of weather forecast data and artificial neural networks (ANNs), solar energy generation in a microgrid can be predicted [49]. In order to identify patterns and relationships in big datasets, ANNs are a form of machine learning technique that is well suited for forecasting complex systems like solar energy generation.

To build an ANN model for solar energy prediction, several steps can be taken, including:

1. Collecting weather data: Accurate weather data, including temperature, humidity, wind speed, and cloud cover, is essential for predicting solar energy generation. This data can be collected from local weather stations or through weather forecasting services.
2. Collecting solar energy data: Historical solar energy generation data for the microgrid can be collected to use as training data for the ANN model.
3. Preparing the data: The weather and solar energy data can be preprocessed to ensure that it is suitable for use in the ANN model. This may include scaling the data, removing outliers, and transforming the data to make it easier for the ANN to learn from.
4. Training the ANN: The prepared data can then be used to train the ANN model. This involves feeding the ANN input data (weather forecast data) and corresponding output data (historical solar energy generation data) and adjusting the weights of the model to minimize the difference between the predicted and actual output values.
5. Testing the ANN: After the ANN model has been trained, it may be put to the test by forecasting solar energy generation using fresh weather data. By contrasting the anticipated and actual solar energy outputs, one may gauge how accurate the model is.

Therefore, employing weather forecast data in a microgrid, an ANN model can be a beneficial tool for forecasting solar energy generation. The model's accuracy will be influenced by the caliber of the weather data as well as the quantity and caliber of the training dataset.

8. Discussion

The evaluation of Microgrid Energy Management using Weather Predictions emphasizes the potential advantages of incorporating weather forecasts [50] into the functioning of microgrid systems. As a result, microgrid operators can forecast the renewable energy sources that will be available and use those sources most effectively, which can save energy bills and carbon emissions. To properly adopt this strategy, there are other issues that must be resolved.

Accuracy of weather forecasts is one of the major issues [51]. Since weather is fundamentally unpredictable, even the most accurate forecasts may contain mistakes. When choosing whether to employ renewable energy sources and when to switch to other energy sources, such as backup diesel generators, the accuracy of the forecasts is essential. The accuracy of the forecasts can be increased through ensemble forecasting, which entails executing several forecasts and averaging the outcomes.

The integration of weather forecast data with the energy management system for the microgrid presents another difficulty. Real-time weather information must be able to be accessed by the EMS and integrated into the microgrid's functioning. In order to accomplish this and incorporate the data into the EMS, specialized software and hardware must be able to interface with weather forecasting systems. Also, the EMS must be adaptable and agile in order to maximize the operation of the microgrid in response to changes in the weather.

A successful example of Microgrid Energy Management utilizing Weather Forecasts may be found in the case study of the Smart Grid [52] Gotland project in Sweden. The project showed the method's ability to use renewable energy sources more frequently while using fewer fossil fuels. It also emphasizes how critical it is to address the difficulties with accurate weather forecasting and the integration of forecast data with the EMS.

The analysis of Microgrid Energy Management using Weather Forecasts as a whole indicates that this strategy has a lot of promise to improve the performance of small-scale power systems [53]. Although there are some issues that need to be resolved, this strategy is anticipated to become more common in the energy sector as a result of developments in weather forecasting and microgrid management systems.

9. Challenges

Using weather forecasts for microgrid energy management presents a number of difficulties, including the following. Accurate weather forecasts are crucial to the microgrid energy management system. Weather predictions, however, are not always accurate, and even minor miscalculations can result in major inefficiencies in the administration of microgrids [54]. This difficulty can be reduced by interpreting the data using numerous weathers forecast sources and cutting-edge algorithms.

Renewable energy sources' variability and unpredictability: Microgrids frequently rely on renewable energy sources like solar and wind power [55]. These sources, nevertheless, are incredibly unpredictable and variable, and the output they provide is greatly influenced by the weather [56]. With such erratic energy sources, managing a microgrid calls for sophisticated energy management systems that can swiftly adapt to variations in supply and demand.

Complicated energy storage management: When using renewable energy sources, energy storage is crucial for the stability of a microgrid. Yet, maintaining energy storage can be difficult because it calls for carefully planning when to charge and discharge batteries in order to reduce energy waste and provide a steady supply of electricity [57].

Management of operating expenses: Operating costs for a microgrid include producing, storing, and distributing energy. It takes a complicated set of calculations and algorithms to optimize these costs, which are greatly influenced by the weather and energy consumption [58].

Effective communication and coordination between numerous stakeholders, such as energy suppliers, grid operators, and customers, are essential for managing a microgrid [59]. Failures in coordination can result in issues like energy imbalances, while communication failures can cause inefficiencies and decreased dependability.

Using weather forecasts to manage microgrid energy is a difficult undertaking that calls for sophisticated algorithms [60], cutting-edge energy storage and management systems, and efficient coordination among stakeholders.

One of the main challenges is the accuracy of weather forecasts. Weather is inherently unpredictable, and even the best weather forecasts can be subject to errors [61]. Another challenge is the integration of weather forecast data with the energy management system (EMS) of the microgrid.

10. Conclusion

In the current study, the use of weather forecasts for microgrid energy management was studied in light of previous scholarly articles. All of the microgrids under examination used renewable energy, which was confirmed. It has also been established that one of the primary goals of the suggested energy management systems is to deal with any deviations from plans brought on by predicting inaccuracies. Thus, the major input for microgrid scheduling issues should be weather data. Despite this, and as a first finding of the literature review, it is noted that the meteorological component plays a secondary role in the majority of the studies, with the meteorological data provided in these papers being scant, dispersed, and occasionally incoherent or not fitting to meteorological standards. A limited number of studies were therefore chosen in order to properly analyze the components and procedures involved in the use of weather forecasts in MG problems. The chosen books gave a thorough description of the forecast framework, including its sources, methodology, horizons, goals, uncertainty, and outcomes. Based on these factors, a thorough study of wind and solar applications for microgrids was carried out. Some challenges have also been discussed in this paper regarding the use of renewable energy sources. Investing in high-resolution weather forecasting models and implementing real-time data integration system could be adopted to improve the accuracy of weather predictions. Deploy advanced energy storage technologies, such as grid-scale batteries or other energy storage systems with fast response times could also be implemented for removing challenges of renewable energy sources involved in energy management system in microgrid. Last but not least, the use of realistic forecasts, lengthy test periods, appropriate use of data sources and metrics, or standardized descriptions are mentioned as challenges for future study and practical implementations.

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