



Application of AI and IoT in Advanced Power Distribution Networks for Enhanced System Efficiency

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ABSTRACT

The integration of distributed components such as advanced power distribution systems, communication infrastructure, and distributed energy resources is transforming the global power system. This integration will increase future reliability, energy efficiency, management, and security. These components are getting increasingly intertwined with IoT. They are expected to produce huge volumes of data for a variety of smart grid applications, such as distributed energy management, load forecasting, grid health monitoring and balancing, defect identification, household energy management, and so on. With these new components and data, artificial intelligence techniques can be utilized to automate and optimize the efficiency of the smart grid. This paper conducts a thorough evaluation of sophisticated artificial intelligence algorithms for distributed smart grid applications. Our research focuses on artificial intelligence techniques to integrate renewable energy resources, energy storage technologies, demand response, grid and energy management, and security. The smart grid involves several entities, including energy producers, markets, and consumers. We will discuss how artificial intelligence and market liberalization can boost the grid's overall societal welfare. Finally, we describe the scientific and societal challenges of integrating and coordinating autonomous devices to produce a genuinely smart grid.

1. INTRODUCTION

The term "smart grid" refers to next-generation energy systems that integrate information and communication technologies with existing energy systems. The ability to transfer data and energy in both directions through communication signals is the main advantage of smart grids over conventional energy systems. Smart energy management and the need for process automation in control, monitoring, and decision-making are closely related to smart grid technologies. According to the literature, intelligent systems applied in the energy sector should provide

solutions to issues such as forecasting production and energy prices, minimizing energy losses, customer needs analyzing issues, and improving energy efficiency.

Among the important developments in optimizing efficiency and effectiveness in the distribution of energy through the electrical grid is the infusion of Artificial Intelligence and the Internet of Things. Artificial intelligence and the Internet of Things are applied through enhancement in this paper to ensure difficult leads to smart grid performance efficiency, minimize energy loss, and ensure effective energy use [1]. AI can predict demand

patterns and anomalies and improve load balancing based on analysis from various grid points data and machine learning techniques. IoT devices, including sensors and smart meters, provide real-time information about energy consumption and equipment performance. Together, these two technologies provide a platform to computerize energy supply and thus optimize the management of the grid [2].

With the growth of industries and urbanization, there is an increasing global requirement for energy, which has become quite a challenge to conventional energy distribution networks. The electrical grids, which have traditionally relied on centralized control and manual interventions, are coming under a lot of pressure due to a more dynamic and sustainable energy landscape [3]. With the trend of fluctuating nature in energy use and increasing renewable energy sources such as wind and solar, traditional energy distribution systems are becoming inadequate. These challenges are proposed to be addressed through the transformation to smart grids, which have advanced technologies like AI and IoT at their back to provide optimized energy distribution and consumption [4].

Smart grids are innovative techniques of electricity management, that require the amplification of digital technology and data-driven decision making. Smart grids contrast with the normal networks of one-way energy flow from the production plants to the customer; they enable energy information back and forth [5]. The effectiveness of the overall energy delivery process promises to gain an enhanced level of monitoring, management, and optimization from the implementation and advancement of the smart grid system. The combination of AI and IoT in a smart grid system may be predictive of changes in demand, provide insight into real-time trends of energy consumption, and respond more efficiently to equipment faults or outages [6].

Artificial Intelligence is what makes smart grids more intelligent. Colossal amounts of data are gathered from sensors, meters, and other IoT devices that can be trained on machine learning algorithms to predict and automate decision-making processes. For example, AI could estimate energy demand by analyzing the consumption

patterns of the past few days, weather conditions, and social activities, and energy providers could then modify the supply accordingly [7]. Furthermore, AI can trace each grid irregularity, whether it is voltage imbalance or equipment breakdown, and hence take preventive measures before it reaches a serious break. Such predictive capability increases the reliability of the grid reduces operational costs due to reduced downtime and makes maintenance plans smoother [8].

IoT enhances AI with devices that supply data necessary for real-time monitoring and control of the energy grid. These devices could be smart meters, sensors, and networked appliances, all spread over the grid, picking up information about equipment performance, energy usage, and system problems [9]. After that, the data is transmitted to a central management system, where AI algorithms process and analyze information to come up with defensible judgments. For example, the Internet of Things-enabled smart meters allows energy companies to track energy usage by each customer in real time for improved grid load balancing and dynamic pricing schemes.

2. THEORETICAL FRAMEWORK

AI and IoT can also optimize the energy distribution from renewable sources in a smart grid. Two examples of such renewable sources are sunlight and wind, whose creation is naturally erratic and dependent on the time of day and weather. Artificial intelligence-enabled smart grids could then accurately forecast the times when renewable energy production is at peak levels and change energy flows to maintain grid efficiency during those times. Grid integration of renewable energy thus assumes a very important place in the quest to cut carbon emissions and consequently achieve a more sustainable energy future. Grid integration of renewable energy, in this regard, is critical in the quest for reductions in carbon emissions and the achievement of more sustainable energy in the future [10]. AI and IoT technologies not only enhance smart grid energy efficiency but also enhance resilience. Many electricity systems today face problems of aging infrastructures, cyber-attacks, and natural disasters. Real-time responses to the interruptions and discovery of grid weaknesses are done by AI systems, which monitor the grid continuously with

the help of IoT sensors [11]. AI systems automate re-routers of energy in the case of a storm by bypassing areas of a power outage to minimize the impact on the customer, ensuring a stable supply of energy. A modern smart grid should be self-healing to remain robust against constantly varying challenges [12].

Despite the big potential regarding increased efficiency in energy distribution, derived from the use of AI and IoT, challenges have remained relatively huge, with some features considered totally unresolved [13]. The simple examples of the challenges are security from IoT devices and the information being passed; hence, as the number of connected devices rises, so does the potential for cyber threats toward key energy infrastructure rise. Keeping such devices safe, and the privacy of the data of the users is core to the general adoption of smart grids. Another technological challenge is the interoperability of different IoT platforms and AI systems. For smart grids to work effectively, they have to develop standardized communication protocols that will allow various devices and systems to communicate seamlessly [14].

Recently, much interest has been devoted to the study of smart meters and smart grids. In particular, the communication architecture, smart grid standards, and processing of smart meter data have been identified as the needs in building the future energy system. The development of applications based on smart meter data has tackled the various interests of the stakeholders involved. Even a survey on the cybersecurity of smart grids has been conducted, which states that flaws in communication could expose the data of the system to security risks [15].

The present paper explores how Artificial Intelligence and the Internet of Things are incorporated into modern electrical grids to raise the efficiency of energy distribution. Some methods that are rooted in AI and shall be covered in this study include machine-learning algorithms for predictive maintenance and load forecasting. Under the Internet of Things, sensors, smart meters, and even decentralized energy management systems will also be covered. These revolve, at large, on catering to the principal aspects of risk arising from the employment of AI

and IoT in smart grids, such as cybersecurity threats, privacy related to data, and interoperability of systems. It further suggests a way forward in mitigating those risks, like improved ways of encryption, secure ways of sharing data, and the creation of industrial standards for the integration of devices that would assure that the smart grid system functions both efficiently and securely [16].

3. LITERATURE REVIEW

Numerous uses in the energy sector are made possible by technological advancements like the Internet of Things (IoT), including load demand management, energy supply, transmission and distribution, power generation, and integration of renewable energy sources. The Internet of Things (IoT) has been selected for use in four primary domains within smart energy systems: (i) business; (ii) smart energy applications; (iii) data transmission networks; and (iv) power generation and terminal hardware/devices. Every research topic is further broken down into a variety of subtopics; for instance, energy operational policy, planning, and systems for energy management are all included in IoT business[17].

Customers in the traditional electrical system are ignorant of their patterns of energy use, which costs money in addition to energy. To increase energy efficiency (EE), criteria for consumer usage and consumption must be regulated. By using a variety of strategies, including financial incentives, subsidized prices, and raising consumer knowledge, the smart grid uses demand-side management (DSM) to save energy. Internet (IoT) is becoming an important resource and energy management partner in smart environments (SE). Smart energy management systems (SEMS) built on smart meters (SMs) and contemporary technologies like the Internet of Things (IoT) must be utilized by DSM. SEMS in the smart grid is more effective when SMs are equipped with IoT-based technology.

A smart grid is basically an electrical grid using advanced digital communication technologies to monitor and control changes in local electricity demand. It also controls the electronic conditioning and control of the production, transmission, and distribution of electrical power. Energy consumers, on the conventional power system, waste both money and energy because of a lack of awareness

regarding their usage habits. This problem is most acute in developing countries where this gap is huge and is often resulting in load-shedding and power outages. Smart grid uses demand side management, or DSM, which involves changing customer energy demand using a number of techniques, including awareness and financial incentives, in an effort to conserve electrical energy. It presents the architecture, design, and implementation of an IoT and cloud computing-based EMS [18]. In the system, a load profile of the user is generated, which can be accessed remotely by the utility company or even by the user. Utility companies can use the obtained load profiles of the consumers in managing and dispatching their incentives to motivate them to change their patterns of energy use.

Various articles are present that discuss the DRM in smart grids, which prevent blackouts and provide economic and environmental benefits for both end-users and energy providers. Modern communication networks have enhanced DRM programs and made power grids smarter. The 5G Internet of Things provides advanced infrastructure to the DRM programs in terms of faster data transfer, greater dependability, increased security, lower power consumption, and a large number of connections. The present research work surveys the possible applications of 5G IoT-based technology and algorithms utilized for DRM in smart grids [19].

Machine learning (ML) is rapidly becoming the most effective tool for improving energy distribution decisions and strengthening consumer interactions. This paper discusses how to leverage ML generation systems to make reasonable resource allocation decisions. Adaptive neural fuzzy inference techniques have been used to anticipate short-term wind and solar energy generation that encourage energy producers to generate electricity and sell it back to the grid at peak rates.

In real-world systems, communication uncertainties including noise, data loss, and time delays are inevitable. These uncertainties' effects on stability and control have been extensively

researched in the past. These problems would still persist, though, and become even more significant when using AI because of its data-driven, data-sensitive nature. The tainted samples would compromise the application's accuracy in addition to tricking the models into learning unrelated information from the uncertainty that would impact how well the models fitted the actual system. Furthermore, as the Internet of Things (IoT) develops, data transfer across communication networks will become more regular and essential, exacerbating the problems. Therefore, it is necessary to guarantee a greater level of communication quality and create reliable AI structures to deal with these uncertainties. Feature extraction techniques such as principal component analysis (PCA), support vector machines (SVM), DT, or predicting techniques like long short-term memory (LSTM) may help estimate relatively accurate signals from raw measurements, which will be an interesting avenue for future research.

This study introduces the Internet of Things (IoT)-inspired four-layer smart grid architecture. The things layer, which is the first layer, is made up of components like actuators and smart sensors that gather data and carry out operations for higher layers. By acting as a middleman and leveraging technologies like 5G backhaul and LPWANs (e.g., Sigfox, NB-IoT, ZigBee, LoRa), the second layer, the Network layer, ensures safe, instantaneous communications between the things layer and higher layers. The central component of the design, the middleware layer, allows AI capabilities and integrates cutting-edge technologies like edge computing, fog computing, and big data analytics. In conclusion, the Application layer unifies solutions for diverse IoT-driven smart grid uses in places like towns, businesses, residences, farms, traffic patterns, and ecosystems[20].

4. METHODOLOGY

This section lays the groundwork for the study and development of the smart grid system using AI and IoT. It outlines the tactics, tools, and goals required to integrate technology into power distribution and energy management. The roadmap of this paper is shown in the given figure:

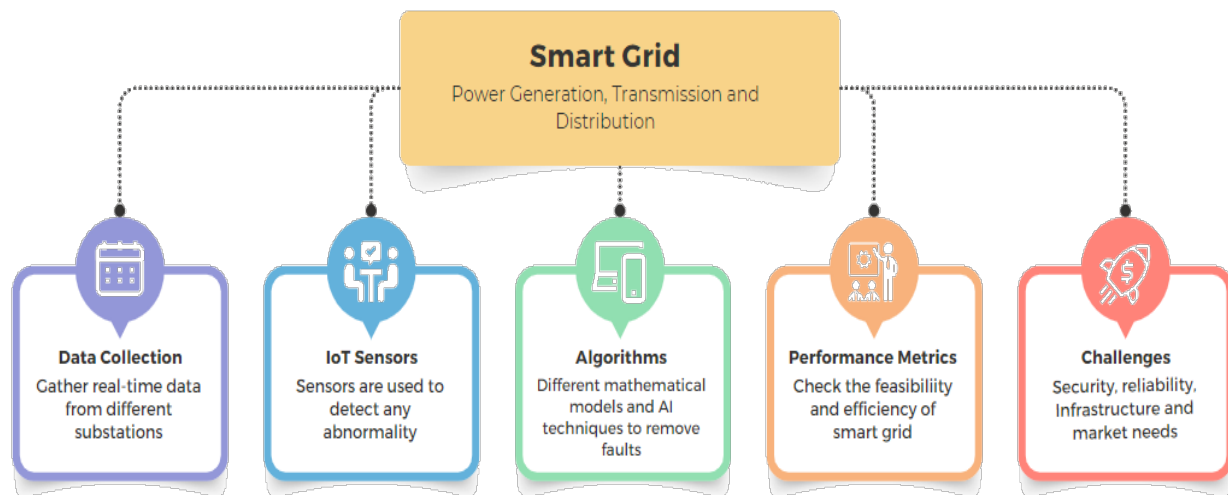


Figure 1: Roadmap for proposed Smart Grid

The scope of this methodology is to implement and improve the efficiency, resilience, and sustainability of the smart grid system. The two major issues to be addressed are:

1. Ensuring real-time and efficient power distribution by utilizing AI algorithms to optimize energy flow and eliminate losses.
2. Energy management entails using IoT devices to monitor, anticipate, and regulate energy consumption, particularly at the consumer level.

The role of Artificial Intelligence in electricity generation optimization, demand forecasting, and fault detection; the role of IoT in real-time monitoring, demand-side management, and grid automation. Also, a deep review of available literature brings out technologies and approaches that have been successfully applied in the existing research, including neural networks, reinforcement learning, and support vector machines. IoT-Based Grid Management: Smart Meters, Remote Monitoring, and Energy Storage Devices. This study of prevalent approaches shall provide a baseline for understanding the potential and limitations of AI and IoT in smart grids, and it shall help make informed design decisions at different phases [21].

It is an important smart grid management technique; by applying this, utilities can predict energy demand, improve generation, and therefore manage resources more efficiently with reduced operating costs. Machine learning techniques are

especially very useful in this task in that they examine vast data to detect patterns and produce accurate predictions. In this context, various machine learning algorithms have been implemented in smart grid load forecasting, some of them being neural networks, support vector machines, and reinforcement learning.

Indeed, each methodology has different advantages with regard to the type of data, the time horizon of forecasting—in the short, medium, or long term—and grid-specific requirements. We will concern ourselves with these algorithms, their basic concepts, how they work, and how they are used in smart grid load forecasting.

Neural networks have been one of the most influential and applied algorithms in load forecasting. Basically, Artificial Neural Networks and Recurrent Neural Networks learn the skills of the human brain in replicating patterns from data and improving prediction accuracy. Neural networks in load forecasting are used to predict future energy use by applying past load information, weather forecasts, day-type variables, temperature variables, and variables representing economic factors [22].

4.1 How does Neural Network (NN) work?

Neural networks consist of layers of connected neurons and nodes. Neurons are entities that take in the input data and predict it by processing it using weights, biases, and activation functions. The number of inputs, which can be past energy consumption and meteorological data, will be supported by the input layer. Neurons in one or more hidden layers will transform data, using

weights and bias applied to the inputs. The final output layer gives the expected load, usually expressed as a single number. In a hidden layer, each neuron performs a weighted summation of the inputs, applies an activation function, and the result is passed to the layer below. A backpropagation algorithm is used to train the network, modifying the weights according to the prediction error.

The first stage in applying neural networks to load forecasting in smart grids is data preparation. This includes gathering all relevant information available that may influence the load, such as load statistics and meteorological conditions. The input is then normalized within a certain range to ensure that the neural network learns well. Any missing or noisy data may further be addressed with methods like imputation or filtering to preserve data integrity. Afterward, the forecasting horizon and the dataset complexity will drive the choice of an appropriate network architecture, ANN, RNN, or LSTM. Accordingly, the number of layers and neurons for the chosen architecture is selected. During the training and validation phase, the network will be trained over the historical data, and its performance will be assessed on another independent validation set. It exploits early stopping and cross-validation methods to ensure the model fits the data effectively without overfitting. Finally, with training on historical data, the network is ready to predict future load levels from real-time input and thus enables grid operators to plan resource allocation and generation/distribution better.

Support Vector Machines have been successfully applied to smart grid systems for tasks such as load forecasting using Support Vector Regression. Smart networks require an accurate energy demand prediction to allow for optimum power generation and ensure efficient distribution while providing dynamic supply and demand balance. For SVM to work, the input data should be mapped into a higher-dimensional space. In the case of smart grids, this will involve the mapping of historical load data, meteorological conditions, and economic considerations. The algorithm subsequently identifies a hyperplane that creates the least prediction error and best fits the data. SVR is used in the load forecasting problem of predicting continuous values, such as future power consumption, by trying to minimize the difference

between the loads anticipated by the model and the actual load.

The kernel trick of SVMs forms a core element for smart grid applications since it is very important in handling nonlinear correlations, normally very frequent in electricity consumption patterns. Smart grids deal with nonlinear data, including weather variations, renewable energy inputs, and customer behavior. SVM nonlinear data transforms into a higher dimensional space in which it builds a model of making a prediction with kernel functions like RBF. Precise data points closest to the hyperplane or support vectors are very critical in determining the direction and accuracy of the prediction.

These would be data to be collected in implementing the SVR on smart grids: the relevant features, such as historical load data, current weather information, and possibly patterns of customer demand. Depending on how complex these features are, an appropriate kernel function will have to be selected; the RBF kernel is commonly used due to its ability to capture nonlinearities. It learns how to predict future energy demand by training the model on past data. In doing so, this step reduces the prediction errors and ensures that the model does not get too close to the training set. To check for the accuracy of the model in projecting future energy demand, the model is checked against an independent data set after it is trained. The trained model is then used in the smart grid to forecast, after validation, real-time energy demand, which allows grid operators to make informed decisions regarding the generation, storage, and distribution of power. The overall efficiency of the grid therefore improves, and the integration of renewable energy sources within the grid is enhanced.

4.2 IoT Methods:

The application of the Internet of Things technology in smart grids revolutionizes the energy network by enhancing communication, automation, and operational efficiency. With an Internet of Things system, utilities can potentially be optimized in terms of generation, distribution, and consumption of electricity by real-time monitoring, data collection, and control of all sorts of distributed energy resources. To that end, the next sections review various IoT-based techniques and algorithms commonly used in smart grids.

Advanced Metering Infrastructure is one of the key features of smart grids; it allows two-way communication between the utility operator and the customer. Internet of Things-enabled smart meters installed at individual households and commercial buildings provide real-time information about energy consumption [23]. The data is accessed directly by the utility company for real-time energy consumption monitoring, after which they apply their dynamic pricing algorithms. Dynamic pricing therefore encourages consumers to shift usage from peak demand times, hence avoiding overloads on the grid, which supports demand management in turn. Besides, smart meters can identify any irregularity or flaw in energy usage and solve it in no time to bring efficiency to the grid [24].

The energy management system for smart grids automates and optimizes energy generation, consumption, and storage by applying Internet of Things-based technologies. The following are tracked and controlled by IoT sensors in real-time: distributed energy resources like solar panels, wind turbines, and energy storage devices. It regulates the energy flows to ensure that there is effective use of renewable resources and energy storage when there is a high demand. Fuzzy logic controllers are utilized in smart grids, which manage uncertainties of energy demands by decision-making with the aid of available data. Smart grid complexities and uncertainties are greatly managed using fuzzy logic controllers, or simply FLCs.

Since FLCs are tailor-made for any dynamic situation, such as smart grids, where energy generation and demand keep fluctuating, they can analyze ambiguous or imprecise information, whereas, in traditional control systems, input data are precise and fixed. Examples of inputs to the FLCs in smart grids include real-time energy demand, renewable energy generation, and meteorological data, which have to be transformed into fuzzy sets. These sets are not used to provide specific figures, but rather to categorize features as having "low," "medium," or "high" demand. The FLCs optimize grid performance by making decisions using established IF-THEN criteria. For instance, the FLCs might reduce the load if the grid frequency is oscillating or turn on energy storage when renewable energy generation is low.

5. DISCUSSION ON THE RESULTS

Imbuing AI and IoT in smart grids has led to tremendous improvements in system operation, efficiency, and stability. These results have been reported based on different performance indicators, such as energy efficiency, load forecasting accuracy, defect detection, demand response, and renewable energy integration. These are the results from field installations, simulations, and smart grid studies. One of the most measurable benefits of smart grids is their very large increase in energy efficiency. This is realized through the combination of IoT-enabled sensors and AI algorithms for effective real-time data consolidation and analytics and to maximize energy distribution and consumption. Several pilots discovered that the employment of AMI and real-time data analytics reduces energy loss because of transmission inefficiencies and poor load control by 15-20%. Traditional grids incurred as much as 20% worth of losses owing to obsolete infrastructure and less dynamic systems. AI-based systems help to dynamically reallocate energy to where it is mostly needed, thereby saving such wastage of energy. This has become true in particular regions after renewables like solar and wind were integrated into the system. All in all, compared with traditional grids, smart networks garnered a 10-15% improvement in overall energy efficiency, leading to a reduction in operational costs and greenhouse gas emissions. On the other hand, load forecasting in smart grids has seen a great improvement in terms of accuracy, mainly due to the application of advanced machine-learning methods: neural networks, long short-term memory, and support vector regression. In most of the case studies, the classical load forecasting accuracy has been raised up to 90-95% by AI models, far above the classical 70-80%. For example, LSTM models have cut the prediction error for short-term load forecasting from 15% to 5%.

IoT devices constantly provide real-time data regarding customer habits and weather. In this way, AI models can adapt forecasts in real time. With this ability, it resulted in more efficient plans for energy generation, particularly in networks that are majorly based on renewable sources. A 30% increase in the accuracy of load forecasting caused more equal distribution of electricity and

fewer occurrences of grid overload. Basically, fault detection in smart grids is now much faster and more accurate when IoT devices are combined with AI-driven anomaly detection algorithms. Concerning real-time energy flow, line voltage, and health of the equipment, this is monitored and detected by Internet of Things sensors positioned across the grid. The data is reviewed by AI systems looking for anomalies that may signal a potential problem before it causes an interruption. It reduced fault detection times from hours down to seconds in one experimental setting.

Load reallocation and automated fault isolation were realized with the use of AI models, such as support vector machines and decision trees, reducing the customer's exposure to the fault and improving grid stability. Now, owing to the incorporation of AI and IoT into smart grids, problem detection and repair time has been reduced by 85%, resulting in more reliable grid operations and fewer outages. The demanded response is, hence, crucial in the balancing of the grid, especially at moments of peak demands. It is in this respect that AI and IoT systems improve peak load control through effective, real-time demand response. Smart meters and other IoT devices provide customers with real-time current energy prices to help customers defer their usage during peak demand moments. According to the research findings, AI-optimized dynamic pricing models raised customer participation in demand response programs by 25%. AI-driven Demand Response systems avoid grid overload at moments of peak demand by reducing peak load by 10%-15%.

Energy sources like wind and solar are variable and hence difficult to integrate into the system. However, with AI and IoT techniques, such resources could be harnessed to the best. AI algorithms were used to predict renewable generation from the historical trends of generation and weather data. This resulted in predictive energy storage management that did an efficient usage of storage. This excess energy, when production is high, is distributed and stored in batteries for use at times of low output. AI-driven energy storage systems optimize the balance of demand and supply in grids with high penetrations of variable renewables by optimizing the timing and efficiency of renewable energy release.

6. CONCLUSION

The combination of AI and IoT transforms conventional power distribution systems by putting them in smart grids. This has brought huge strides forward in energy management, efficiency, and reliability. At the present moment, smart grids perform exceedingly well on load forecasting accuracy and are designed for optimum resource utilization with advanced machine learning techniques such as Artificial Neural Networks and Support Vector Machines. These include sophisticated technologies that have made estimates of demands more accurate and the generation of energy more efficient in order to reduce the wastage of energy through achieving a supply/demand balance.

IoT-enabled smart grids allow real-time monitoring and two-way communication. This includes utilities and consumers who can now have a better, in-depth understanding of energy usage trends and dynamic adjustments. Advanced Metering Infrastructure and Energy Management Systems provide critical data on improved power flow, reduced transmission losses, and better demand-side management. Due to the automation of energy use—made possible by means of IoT sensors—the assurance of operational efficiency and costs is provided both to the consumer and utility companies [25].

AI-driven predictive maintenance in smart grids offers 75% improved reliability in grid operation by reducing the duration of outages and preventing probable equipment breakdowns through the application of predictive analytics. Faster fault recovery time can be achieved through AI-driven self-healing mechanisms, hence reducing grid downtime, which is rather high over traditional grids often manual in operation. Besides, DR algorithms provide real-time load control that helps reduce grid pressure during peak hours and achieves 10-15% reductions in peak energy demand.

One of the other major advantages smart grids have over traditional systems is the seamless integration of renewable energy sources. AI-based optimization ensures that variable energy sources, such as solar and wind, are properly handled, reducing disruptions and allowing up to 80% renewable energy penetrations.

Cyber-secure smart grids come with AI-powered systems that detect and act on any possible cyber

threats more rapidly than traditional grid systems. The scalability and adaptability of smart grids meet the increasing demands posed by today's energy environment—increased usage of electric vehicles and distributed energy resources, for example. With fast-changing dynamics in the energy scene, smart grids offer future-ready infrastructure that can handle present and emerging challenges.

On the issue of performance evaluation, smart grids outshine conventional grids in all aspects. They give better energy efficiency, improved reliability, better power quality, and are quicker to restore themselves from faults and blackouts. They give customers more control over their energy use while reducing energy losses, cost of operation, and environmental degradation.

In summary, smart grids—being an integration of both IoT and AI technologies—would create an extremely intelligent, adaptive, and resilient energy infrastructure that would be able to adapt itself to meet the growing needs for the delivery of sustainable, reliable, and efficient electricity. Smart grid adoption will definitely increase with the development of smarter infrastructures and seeking improvement in energy solutions across nations; these systems will be basic in forming future energy systems.

• **Recommendations & Future Directions**

One of the major questions that remain unanswered in IoT-enabled applications is energy acquisition. Another way in which using blockchain in smart cities may increase security includes enabling robust transactions in a secure, transparent, and unchangeable record. However, a lot of research and development is required for the full integration of blockchain with the smart grid. As a remedy, new energy harvesting technologies should be developed in tandem with IoT devices. The power supply devices should be affordable, reliable, and efficient. In using the IoT in the smart grid, several challenges come up. From the view of smart grids, future research is most specifically AI, deep learning, and IoT that would transform power distribution, energy management, and grid resilience. These technologies will make smart grids more flexible, efficient, and sustainable by answering the critical questions of how renewable energy is integrated, ensuring cyber security, demand response, and system resilience. Deep learning will be important in developing predictive analytics and real-time decision-making.

Blockchain and edge computing will help empower decentralized and secure energy management. Further research will be an essential component in meeting that same need for increasing cleaner, smarter, and more resilient power infrastructure as the energy environment evolves.

The computing model, which involves a collection of computer resources in the form of servers, storage, and services, is what cloud computing is. Cloud computing mainly aims to facilitate fast and easy access to such resources. Thus, the computing model can be implemented using IoT-enabled smart grids or cloud IoT. Further research is still needed to clearly understand the concept of cloud IoT.

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