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# An Optimized Machine Learning Framework for Smart Grid Energy Management

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**Abstract:** *The rising need for reliable, efficient and sustainable electricity in modern power systems is stimulating the advancement of smart grid (SG) technologies. Smart grid (SG) technologies are a fast-growing area of the modern power system where their application is increasing due to the need for reliable, efficient and sustainable electricity. Renewable energy resources, distributed energy and advanced communications systems are all interconnected, making the management of energy more complex, and intelligent and optimized decision strategies are required to handle that complexity. This survey seeks to give an overview of optimized machine learning (ML) frameworks for SG energy management. It includes smart grid architecture, energy management systems, ML techniques, optimization methods and their applications, load forecasting, demand response, renewable energy integration, energy consumption optimization, fault detection, and real-time decision making. Furthermore, recent research is discussed that investigates key contributions, current constraints and new trends in research. The survey also considers some of the major challenges, including cybersecurity, scalability, data quality/computational complexity, among others, and outlines future research directions. The results collectively show that the optimized ML frameworks can significantly enhance forecasting accuracy, operational efficiency, grid reliability, and utilization of renewable energy sources, establishing a robust basis for intelligent, resilient, and sustainable smart grid energy management.*

**Keywords:** Smart Grid, Machine Learning, Energy Management, Load Forecasting, Renewable Energy Integration, Energy Optimization, Intelligent Power Systems

## I. INTRODUCTION

Energy demand has experienced fast development worldwide, as cities are rapidly growing, and energy resources including renewable energy are becoming increasingly intelligent and interconnected [1]. The modern power network is expected to provide reliable and efficient electricity supply, be sustainable and flexible to accommodate a variety of energy sources and dynamic consumption patterns. Smart grids are the new advanced solution that combines power infrastructure with digital communication and information technology for this purpose [2]. Through real-time monitoring, bidirectional communications, and automated control, smart grids boost energy system operations, ensuring a resilient and sustainable system.

Smart grids, which operate on more complex power networks, rely heavily on energy management. Because of the highly unpredictable supply and demand, renewable energy systems, electric vehicles, smart meters, and distributed energy resources produce massive amounts of data. Thus, energy management systems primarily aim to reduce operational costs and maximize efficiency in the electrical grid by minimizing losses and optimizing production, distribution, and consumption of energy [3][4]. The efficient use of energy resources: reduces energy waste and carbon emissions, and ensures electricity supply to consumers.

Machine learning (ML) in energy management has seen vast opportunities open up due to the availability of a lot of smart grid data. The ML can analyze complex data sets, finding patterns, forecasting future conditions, and aiding in data-informed choices. Powerful methods like supervised and unsupervised learning, reinforcement learning, and DL have been used in many areas, including predicting loads, managing demand, finding bugs, saving energy, and planning for green energy. These properties improve the smart grid's intelligence and adaptability, respectively, and make the smart grid more efficient and autonomous [5].

However, there are certain challenges that have to be overcome in the development of optimized ML frameworks to support smart grid energy management. The data quality, scalability, computational demands, cybersecurity, privacy, and real-time decision-making are the challenges faced by the advanced learning models when applied in practice [6]. Additionally, the wide variety of ML algorithms and optimization strategies has resulted in a fragmented research field that has become difficult to decide which is optimal for a particular application. Therefore, a comprehensive review of the existing methodologies is required to assess their effectiveness and applicability under real conditions.

### 1.1 1.1 Structure of the Paper

The paper's structure is as follows: Section II provides an overview of smart grid, Section III summarises relevant literature, Section IV delves into machine learning techniques, Section V examines optimal frameworks and applications, and Section VI addresses challenges and potential solutions. Section VII concludes the paper.

## II. FUNDAMENTALS OF SMART GRID ENERGY MANAGEMENT

The term "smart grid energy management" refers to a system that integrates communication networks, intelligent control mechanisms, and cutting-edge power system technology to efficiently manage power generation, distribution, and consumption. Compared to conventional electricity grids, smart grids are more reliable, environmentally friendly, and efficient to run because they include features like automated decision-making, bidirectional communication, and real-time monitoring. Intelligence in energy management is becoming more important as renewable energy, electric vehicles, and distributed energy supplies continue to gain traction [7]. To design optimized ML frameworks for smart grid applications, it is crucial to understand the basic architecture, working components, communication infrastructure, challenges, and performance evaluation measures.

### 1. Smart Grid Architecture and Components

Smart grid architecture is complex and comprises both the physical and digital aspects needed to enable efficient generation, transport, distribution and use of energy [8][9]. All of these parts work together to provide more reliable grid operations, automated control, and real-time monitoring.

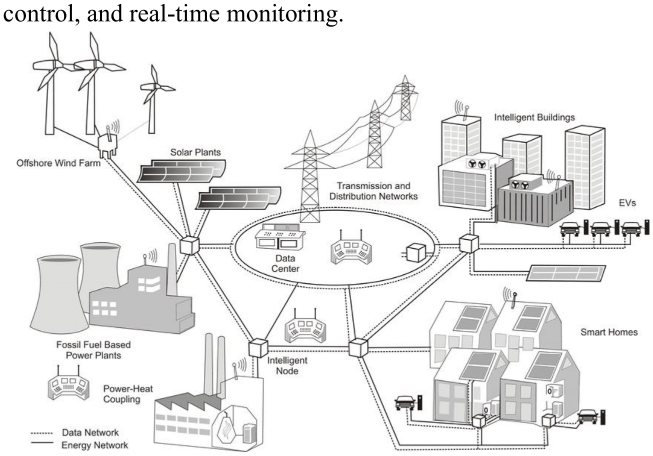


Figure 1: Smart Grid Architecture[10]

The smart grid architecture is shown in Figure 1 with energy generation, communication network, intelligent control and end-user systems.


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• Smart Meters: These allow the utility company to track the customer's actual power consumption in real-time. They enable accurate billing, demand side management and energy consumption analysis [11].

• Distributed Energy Resources (DERs): Renewable energy resources such as wind, solar, and batteries. They are more energy flexible and distribute energy production.

• Control Centers: The grid's functions are monitored and decisions are made at these Control Centers that receive real-time data from various parts of the grid. These are important to the stability and reliability of the system.

• Sensors and Monitoring Devices: These are sensors installed throughout the grid used to sense the voltage and current readings, frequency and device status. Faults and operational anomalies can be quickly identified with these devices.

• Communication Networks: Communication systems are used to relay information between consumers and utility providers and control centers, which helps to coordinate and manage the grid more efficiently [12].

**2. Energy Management Systems (EMS)**

EMS is a software-based platform that is used to monitor, control and optimize the generation, storage and consumption of energy in a smart grid environment [13]. EMS is the intelligence system of the entire system and is integral to decision-making and optimization of resources.

EMSs typically have three main objectives: to balance electricity demand and supply, to keep electricity system costs low, and to keep the electricity system reliable. The latest EMS solutions include complex analytics, optimizations, and ML algorithms that enhance the reliability of forecasts and enable automated control actions. Various grid elements through EMS boost operational efficiency and allow for efficient use of renewable energy sources.

**3. Key Challenges in Smart Grid Operations**

The advantages of smart grid technology are numerous, while there are also some operational and technical challenges to implementing smart grids [14].

**• Integration of Renewable Energy Sources**

Energy production from renewable sources depends on weather conditions and wind and sun are unpredictable and intermittent. This also makes it harder to balance the energy equation and to make the grid more stable.

**• Data Management Complexity**

Sensors, smart meters, and other monitoring devices in smart grids produce massive amounts of data. It remains challenging to store, process and analyze this kind of data effectively.

**• Cybersecurity Threats**

Critical infrastructure is also susceptible to cyberattacks, unauthorized access and data breaches because of the connectivity provided by smart grids, which can affect system security [15].

**• Scalability Issues**

Efficient communication and computational performance are increasingly challenging as more devices and distributed resources are added.

**• Real-Time Decision Making**

Smart grid applications typically require immediate reaction to changes in the operating environment, requiring rapid and accurate analytical methods.

**4. Data Sources and Communication Infrastructure**

Reliable data and communication technology are crucial to the success of smart grid energy management [16]. The data is collected from various sources for monitoring, forecasting and optimizing activities and the important Data Sources Include:

• Smart Meter Data: Offers in-depth data analytics on electricity usage and customer behavior.

• Renewable Energy Generation Data: The data utilized for renewable energy forecasting includes solar irradiance, wind speed, temperature, and electricity generation from renewable sources.

• Grid Monitoring Data: Information collected by sensors and SCADA systems to assess the state and efficiency of the grid.
• Weather and Environmental Data Weather is very crucial input in the predictive models because energy demand and renewable energy production are significantly influenced by the environment.

## III. MACHINE LEARNING TECHNIQUES FOR SMART GRID ENERGY MANAGEMENT

Smart meters, sensors, renewable energy monitoring and other smart grid technologies are proliferating, creating a lot of information from smart meters. Most traditional analysis approaches are not suitable for complex and dynamic data sets [17]. Thus, ML has become a significant solution for gaining useful information, enhancing decision making and optimizing energy management processes. ML is useful in smart grid operations for a variety of reasons, including prediction, finding outliers, intelligent control, and optimizing demand response, all of which contribute to smart grid operations' efficiency, dependability, and sustainability [18]. Several ML approaches, including supervised and unsupervised learning, reinforcement learning, DL, and hybrid methods, have been investigated with the purpose of solving smart grid issues.

### A. Supervised Learning

Supervised learning techniques are now widely used for energy management applications because of the availability of historical smart grid data. These techniques are based on labeled data sets and are widely used for load forecasting, energy consumption prediction, fault classification and demand estimation. It is observed that linear regression, SVM, RF and DT are useful algorithms for improving the accuracy in forecasting and for supporting data-driven decision making in smart grid environment.

### B. Unsupervised Learning

The significant amount of unlabeled data coming from the smart grid has driven the use of unsupervised learning methods to discover patterns and relationships. The techniques are primarily applied in the areas of consumer segmentation, anomaly detection, and energy consumption analysis. Furthermore, clustering and dimensionality reduction algorithms help utilities understand user behaviour, detect unusual system conditions and make the most efficient use of resources without requiring pre-defined labels in the output.

### C. Reinforcement Learning

Reinforcement learning is a potential solution in the smart grid as the operating conditions are dynamic and uncertain. The agents are then able to sample the environment and learn from the reward feedback; they are able to find the optimal actions [19]. Demand response management, energy storage optimization, microgrid control, and real-time energy scheduling are just a few of the applications where reinforcement learning has been successful in improving operational flexibility and resource utilization.

### D. Deep Learning Models

As smart grid data has become more complex and voluminous, more and more DL methods have been used in more sophisticated energy management systems. DL models, such as ANNs, CNNs and LSTM networks, can recognize complex nonlinear patterns in large volumes of information. These models have been shown to be very successful in defect detection, load forecasting, renewable energy forecasting, and grid monitoring, enhancing smart grid operations with increased intelligence and dependability.

### E. Hybrid and Ensemble Learning Methods

Ensemble and hybrid learning strategies are gaining more attention in the research field as a solution to the limitations of individual ML techniques. These methods include multi-models and/or the inclusion of optimization methods and

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ML algorithms for improved predictions, robustness and computational efficiency. They are potential solutions that can be integrated into future energy management frameworks inside smart grids, such as load forecasting, renewable energy resource management, and energy optimization, and they have been shown to enhance the system's overall performance.

## IV. OPTIMIZED MACHINE LEARNING FRAMEWORKS AND APPLICATIONS

Modern power systems are getting more complex, and the development of efficient ML frameworks to improve system operation, reliability, and sustainability is being developed [20]. These frameworks combine predictive analytics, intelligent control strategies, and optimization techniques to aid in decision-making for different smart grid applications. This adoption has helped utilities optimize their energy management, adapt to fluctuating demand, and optimize overall energy performance.

### A. Load Forecasting and Demand Prediction

Smart grid energy management relies heavily on demand electricity predictions. ML-based models are able to forecast energy demand in the near and distant future by analyzing consumption patterns, weather patterns, and consumer usage trends [21]. Accurate forecasting can help utilities better schedule their electricity production, lower operational expenses, and balance supply and demand. Additionally, state-of-the-art prediction models help with optimal resource management and incorporate renewable energy resources.

### B. Demand Response Management

The demand for electricity is growing more unpredictable, thus smart systems are needed to control consumption without compromising user satisfaction [22]. ML can be applied to a demand response program by analyzing consumption patterns and identifying load shifting opportunities when the demand is high, and the main advantages are:

- Lower peaks of electricity demand and network congestion.
- Better use of energy resources.
- Increased Consumer involvement with dynamic pricing.
- More flexibility and cost-effectiveness in operation.

### C. Renewable Energy Integration

The fact that renewable energy sources like solar and wind power do not provide a constant supply of electricity has also introduced additional difficulties. ML models can be used to provide accurate generation forecasting, efficient resource scheduling, and better integration of renewables with conventional generation systems [23]. These features have the potential to improve grid dependability and promote the usage of sustainable energy.

### D. Energy Consumption Optimization

In smart grid energy management, maximizing the efficiency of power resources is a top priority. ML models can be used to optimize and identify inefficiencies and energy-saving solutions [24].

- Minimize use of all energy.
- Reduce operating and maintenance expenses.
- Energy Efficiency Enhancement of Residential, Commercial and Industrial Sector.
- Enhancement of energy use sustainability.

### E. Fault Detection and Grid Stability Enhancement

Faults and Abnormal operating conditions are important for reliable grid operation to detect. The operational data is injected into the ML techniques which enable disturbance detection and equipment failure prediction, and provide assistance for preventive maintenance [25]. This helps to make the system reliable and power quality and helps to stabilize the grid.

**F. Real-Time Decision-Making System**

The information from the smart grid system is continuously analyzed and monitored intelligently and decisions are taken dynamically at suitable times. Systems based on ML are able to manage energy scheduling, resource allocation, and to respond rapidly to changes in demand and unforeseen events. This is because it can increase the power network efficiency and flexibility.

## V. CHALLENGES, AND FUTURE DIRECTIONS IN SMART GRID ENERGY MANAGEMENT

Smart grid technologies have also experienced a drastic change and are currently contributing greatly to the energy efficiency, reliability and sustainability of smart grid. Nevertheless, several technical, operational, economic and security problems exist that must be resolved before their viability and efficiency can be realized on a broader scale [26]. The smart grid of tomorrow is smart, adaptable, sustainable and intelligent in responding to the needs of the future, addressing these challenges with the cutting edge of artificial intelligence technology, secure communication networks, interoperable architectures and resilient energy management solutions.

• Cybersecurity and Data Privacy: Connectivity of smart grid devices introduces vulnerability to critical infrastructure in the areas of Cybersecurity and Data Privacy. Strong encryption, authentication, and AI-powered intrusion detection are essential for securing grid operations. In grid operations, AI is crucial for intrusion detection, secure encryption, and user authentication, which are key elements of grid security [27].

• Renewable Energy Intermittency: Solar and wind resources are variable, causing fluctuations in energy supply and impacting energy balancing and grid stability. This challenge requires advanced forecasting and intelligent use of energy.

• Scalability and Integration: The multitude of distributed energy resources, EVs and IoT devices creates an even more complex system. The architectures and communication protocols should be designed to be scalable to ensure smooth interoperability and efficient grid functioning.

• Real-Time Data Processing: Smart Grids are generating tremendous amounts of complex and diverse data which require real-time analysis to take action. To reduce latency and responsiveness, efficient AI algorithms and edge computing solutions are required.

• Infrastructure Modernization: The current power networks were constructed on top of obsolete infrastructure, incompatible with the smart grid technologies. A considerable investment is required in communication, sensing and automation systems.

Future Directions

• Explainable and Trustworthy AI: Future smart grids should also have models that are explainable with high prediction accuracy, improving the transparency of the decision-making process, increasing the confidence of the smart grid operators and assisting the smart grid operators to fulfill regulation requirements.

• Edge Computing and Federated Learning: Utilizing federated learning and edge intelligence can alleviate communication latency, resolve consumer privacy concerns, and enable a decentralized smart grid energy management system.

• Digital Twin-Based Smart Grids: Digital twin simulates, predict, diagnose, and optimize digital twin operations, improving the resilience of digital twin operations, and cutting maintenance costs.

• Blockchain-Enabled Energy Trading: Blockchain technology has the potential to create new local energy markets, provide transaction security and integrity, and enable the decentralized, safe, and transparent movement of energy between people.

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• AI-Driven Autonomous Grid Management: Autonomous grid management systems powered by AI should be the focus of future studies. These systems should be able to detect and fix problems, optimize energy usage, and intelligently manage energy demand response.

## VI. LITERATURE REVIEW

The literature review comprises the recent developments in energy management using Artificial Intelligence, ML, IoT and smart grid technologies. It highlights the significant methodologies, contributions, and existing limitations and gaps in the research that drive the proposed optimized ML.

O. O. Olagundoye et al., (2026), give an exhaustive overview of the ways AI is being used in smart grid and smart home applications to manage energy sustainability and integrate low-carbon technologies. For real-time prediction, adaptive scheduling, and energy model optimization, it details various AI methodologies, such as ML, DL, and bio-inspired optimization algorithms. The company has a stellar reputation for its effective use of renewable energy, load balancing, and demand-side management. To address these and other key challenges, such as data heterogeneity, computational cost, and integration, AI models that are scalable, lightweight, and interpretable are needed for future smart energy systems [28].

Z. Mingya (2026), introduces the details of intelligent energy management systems with the aid of AI and ML. It delves into techniques such as DL, supervised learning, and demand response for tasks including predictive maintenance, renewable energy integration, load forecasting, and demand response. Improved electrical system efficiency, savings, and dependability are achieved through the use of predictive analytics. It also examines some of the challenges, including the quality of data, computational complexity, regulatory oversight, data privacy and algorithmic bias as applied to the AI-based energy management system [29].

R. Goswami, R. Roy, and K. K. Mandal, (2025), This paper explores the use of advanced ML techniques to optimize demand response and energy efficiency in power systems that incorporate large amounts of renewable energy. Some of the most fundamental uses of these models include demand-side management, optimization of storage systems, detection of anomalies, forecasting of load and renewable generation, and a plethora of others. The article also discusses major challenges, including cybersecurity threats, computational load, data shortages, and regulations. ML is finding increasing use in utility operations, as shown by several applications and experimental projects [30].

A. Fathollahi (2025), explores potential AI and ML uses to enhance smart grid and EMS reliability. This article takes a look at the many AI and ML frameworks and algorithms that are used for managing distributed energy systems, predicting loads, creating backup plans, controlling voltage and frequency, and detecting faults. Popular algorithms including SVMs, DTs, ANNs, and Deep Q-networks are also covered in the article, all of which are being used to make the smart grid more reliable and practical [31].

M. Kiasari, M. Ghaffari, and H. H. Aly (2024) explain the smart grid and why it's crucial to incorporate RES like solar and wind to make the system more sustainable and reliable. It takes a look at how several important smart grid technologies, like AMI, DCS, and SCADA, contribute to the grid's reliability, efficiency, and resilience. Additionally, it investigates how ML and optimization methods might be used to optimize and manage energy in smart grids [32].

T. Mazhar et al., (2023) The goal of this study is to ascertain why IoT devices are installed in smart buildings and the grid. This viewpoint is crucial for comprehending the infrastructure supporting IoT devices as well as the essential elements that comprise an IoT device. Smart grid monitoring can be configured remotely to offer more security and comfort to the building occupants. Consumer electronics to SGs – sensors required to operate and monitor. Use less energy to be remotely monitored by network-connected devices [33].

The most recent research papers on ML-based smart grid energy management, highlighting the focus of the research, main contributions, advantages, disadvantages, and recommendations for future work are summarized in Table II. It is a comparison that identifies gaps and the need for a more optimized, scalable and intelligent framework.

TABLE II. SUMMARY OF LITERATURE REVIEW ON OPTIMIZED MACHINE LEARNING FRAMEWORK FOR SMART GRID ENERGY MANAGEMENT

| Authors | Study on | Contributions | Advantages | Limitations | Recommendations |
|---|---|---|---|---|---|
| O. O. Olagundoye et al. (2026) | AI for sustainable energy management in smart grids | Reviewed ML, DL, and bio-inspired optimization for forecasting, scheduling, and energy optimization | Improved demand-side management and renewable energy utilization | Data heterogeneity, computational overhead, integration challenges | Develop lightweight, scalable, and explainable AI-based energy management models |
| Z. Mingya (2026) | AI and ML in intelligent energy management systems | Surveyed supervised, reinforcement, and deep learning for forecasting and predictive maintenance | Enhanced grid reliability and operational efficiency | Data quality, privacy, computational complexity, algorithm bias | Design secure, privacy-preserving, and efficient ML frameworks |
| R. Goswami et al. (2025) | ML for demand response and renewable energy integration | Discussed forecasting, storage optimization, and anomaly detection using advanced ML models | Improved energy efficiency and utility performance | Limited datasets, cybersecurity issues, regulatory constraints | Develop robust ML models with enhanced security and real-world adaptability |
| A. Fathollahi (2025) | AI/ML for smart grid stability | Reviewed ML techniques for forecasting, fault detection, voltage and frequency control | Increased grid stability and operational reliability | High computational complexity and limited practical implementation | Developed real-time and computationally efficient ML frameworks |
| M. Kiasari et al. (2024) | Smart grid technologies and renewable energy integration | Reviewed AMI, DCS, SCADA, and ML-based energy management | Improved grid resilience, efficiency, and sustainability | Limited optimization for dynamic grid environments | Developed adaptive ML optimization frameworks for real-time smart grid operation |
| T. Mazhar et al. (2023) | IoT infrastructure for smart grids and buildings | Explored IoT-enabled monitoring and energy-efficient smart building applications | Enhanced remote monitoring and energy efficiency | Security vulnerabilities and interoperability issues | Integrate secure IoT with optimized ML for intelligent energy management |

## VII. CONCLUSION AND FUTURE WORK

Smart grid technologies are continuously developing and evolving and have great potential for smart and efficient energy management. This survey gave a thorough overview of optimized ML frameworks for smart grid energy management including introduction to smart grid, introduction to ML, introduction to optimization methods, and applications. Several advances, current gaps and new research directions were identified in the literature review. The results show that ML with optimization methods increases the accuracy of predictability, operational efficiency, grid reliability, and utilization of renewable energy. There are, however, implementation problems that cannot be ignored, such as cybersecurity, scalability, as well as data quality and real-time processing. Lastly, this survey provides systematic introduction to the state of the art in the field of energy management research, which may help in the design of an intelligent energy management system to make the smart grid a reliable and sustainable system.

The research areas that need to be developed are: lightweight explainable and secure ML frameworks for edge, federated learning, Digital twins, Blockchain technology etc. The developments can enable a real-time optimization, autonomous grid management, scalability and sustainable smart grid energy management.

## REFERENCES

[1] I. Alotaibi, M. A. Abido, M. Khalid, and A. V Savkin, “A Comprehensive Review of Recent Advances in Smart Grids: A Sustainable Future with Renewable Energy Resources,” Energies, vol. 13, no. 23, p. 6269, 2020.

[2] G. Dileep, “A survey on smart grid technologies and applications,” Renew. Energy, vol. 146, pp. 2589–2625, 2020.

[3] S. K. Rathor and D. Saxena, “Energy management system for smart grid: An overview and key issues,” Int. J. Energy Res., vol. 44, no. 6, pp. 4067–4109, 2020.

[4] S. Sen, “AI-Enabled Substation Architectures for Autonomous Power Systems: Reliability, Asset Intelligence, and Grid-Edge Analytics,” Int. J. Comput. Trends Technol., vol. 74, no. 2, pp. 11–15, February, 2026.

[5] P. Thollander et al., “Advances in the social construction of energy management and energy efficiency in industry,” Nat. Commun., vol. 16, no. 1, p. 4075, 2025.

[6] H. N. Noura, J. P. A. Yaacoub, O. Salman, and A. Chehab, “Advanced Machine Learning in Smart Grids: An overview,” Internet Things Cyber-Physical Syst., vol. 5, pp. 95–142, 2025.
[7] S. Lalit, “Smart Grid Architecture: An Overview,” in 2025 IEEE International Conference on Power Systems and Smart Grid Technologies (PSSGT), 2025, pp. 225–229.
[8] A. Ghasempour, “Internet of Things in Smart Grid: Architecture, Applications, Services, Key Technologies, and Challenges,” Inventions, vol. 4, no. 1, pp. 1–12, 2019.
[9] A. Joon, “Smart Predictive Maintenance: AI-Driven Adaptation for Industrial Equipment,” in 2025 IEEE North-East India International Energy Conversion Conference and Exhibition (NE-IECCE), 2025, pp. 1–6.
[10] O. Mahela et al., “Comprehensive overview of multi-agent systems for controlling smart grids,” CSEE J. Power Energy Syst., pp. 1–16, November, 2020.
[11] A. T. Yee Chong, M. A. Mahmoud, F.-C. Lim, and H. Kasim, “A review of Smart Grid Technology, Components, and Implementation,” in 2020 8th International Conference on Information Technology and Multimedia (ICIMU), 2020, pp. 166–169.
[12] S. Singh, S. A. Pahune, P. Chatterjee, and R. Sura, “Advanced Machine Learning Techniques for Prediction of Customer Churn in Telecommunication Sector,” in 2025 IEEE 6th India Council International Subsections Conference (INDISCON), 2025, pp. 1–6, August.
[13] O. D. Segun-Falade, O. S. Osundare, W. E. Kedi, P. A. Okeleke, T. I. Ijomah, and O. Y. Abdul-Azeez, “Developing innovative software solutions for effective energy management systems in industry,” Eng. Sci. Technol. J., vol. 5, no. 8, pp. 2649–2669, August, 2024.
[14] S. R. Salkuti, “Challenges, issues and opportunities for the development of smart grid,” Int. J. Electr. Comput. Eng., vol. 10, no. 2, pp. 1179–1186, April, 2020.
[15] V. K. Bollu, “Threat Landscape in Artificial Intelligence Systems: Taxonomy, Attack Vectors and Security Implications,” World J. Adv. Res. Rev., vol. 29, no. 1, pp. 285–294, 2026.
[16] M. Ghorbanian, S. H. Dolatabadi, M. Masjedi, and P. Siano, “Communication in Smart Grids: A Comprehensive Review on the Existing and Future Communication and Information Infrastructures,” in IEEE Systems Journal, 2019, vol. 13, no. 4, pp. 4001–4014.
[17] W. Ahmed et al., “Machine Learning Based Energy Management Model for Smart Grid and Renewable Energy Districts,” in IEEE Access, 2020, vol. 8, pp. 185059–185078.
[18] A. R. Singh, R. S. Kumar, M. Bajaj, C. B. Khadse, and I. Zaitsev, “Machine learning-based energy management and power forecasting in grid-connected microgrids with multiple distributed energy sources,” Sci. Rep., vol. 14, no. 1, p. 19207, 2024.
[19] S. Sen, “Data Stewardship: How AI Agents Form the Pillars for Effective Data and AI Governance,” Int. J. Emerg. Trends Comput. Sci. Inf. Technol., vol. 5, no. 4, pp. 151–155, December, 2024.
[20] P. Bouquet, I. Jackson, M. Nickc, and A. Kaboli, “AI-based forecasting for optimized solar energy management and smart grid efficiency,” Int. J. Prod. Res., vol. 62, no. 13, pp. 4623–4644, Sep, 2023.
[21] H. Habbak, M. Mahmoud, K. Metwally, M. M. Fouda, and M. I. Ibrahem, “Load Forecasting Techniques and Their Applications in Smart Grids,” Energies, vol. 16, no. 3, p. 1480, 2023.
[22] E. Sarker et al., “Progress on the demand side management in smart grid and optimization approaches,” Int. J. Energy Res., vol. 45, no. 1, pp. 36–64, 2021.
[23] C. P. Ohanu, S. A. Rufai, and U. C. Oluchi, “A comprehensive review of recent developments in smart grid through renewable energy resources integration,” Heliyon, vol. 10, no. 3, p. e25705, Feb. 2024.
[24] B. S. Mahdi, N. Sulaiman, M. A. Shehab, S. Shafie, H. Hizam, and S. L. B. M. Hassan, “Optimization of Operating Cost and Energy Consumption in a Smart Grid,” IEEE Access, vol. 12. pp. 18837–18850, January, 2024.
[25] M. Ibrahim, M. A. Mahmoud, N. Islam, and S. S. Gunasekara, “Enhancing Smart Grid Stability Using AI Techniques: A Systematic Literature Review,” in 2025 21st IEEE International Colloquium on Signal Processing & Its Applications (CSPA), 2025, pp. 50–55, March.

[26] M. S. Bakare, A. Abdulkarim, M. Zeeshan, and A. N. Shuaibu, "A comprehensive overview on demand side energy management towards smart grids: challenges, solutions, and future direction," Energy Informatics, vol. 6, no. 1, p. 4, 2023.
[27] D. Bhattacharjee, "Design and Evaluation of Deep Generative AI Model for Intrusion Detection in Cyber Threat Monitoring," in 2025 7th International Symposium on Advanced Electrical and Communication Technologies (ISAECT), 2025, pp. 1–6, December.
[28] O. O. Olagundoye, O. Bamisile, C. Joseph Ejiyi, O. Bamisile, T. Ni, and V. Onyango, "A Review of Artificial Intelligence Techniques for Low-Carbon Energy Integration and Optimization in Smart Grids and Smart Homes," Processes, vol. 14, no. 3, pp. 464, JanuaryMingya, Zhang, Artificial Intelligence, 2026.
[29] Z. Mingya, "Artificial Intelligence and Machine Learning for Intelligent Energy Management in Smart Grids." pp. 1–33, Feb, 2026.
[30] R. Goswami, R. Roy, and K. K. Mandal, "A Comprehensive Review of Machine Learning Techniques for Enhancing Energy Efficiency in Renewable Integrated Smart Grids," in 2025 International Conference on Power Electronics and Energy (ICPEE), 2025, pp. 1–6, December.
[31] A. Fathollahi, "Machine Learning and Artificial Intelligence Techniques in Smart Grids Stability Analysis: A Review," Energies, vol. 18, no. 13, pp. 3431, June, 2025.
[32] M. Kiasari, M. Ghaffari, and H. H. Aly, "A Comprehensive Review of the Current Status of Smart Grid Technologies for Renewable Energies Integration and Future Trends: The Role of Machine Learning and Energy Storage Systems," Energies, vol. 17, no. 16, pp. 4128, August, 2024.
[33] T. Mazhar et al., "Analysis of Challenges and Solutions of IoT in Smart Grids Using AI and Machine Learning Techniques: A Review," Electronics, vol. 12, no. 1, pp. 242, January, 2023.