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INTRODUCING ARTIFICIAL INTELLIGENCE INTO THE MANAGEMENT AND DISTRIBUTION OF ELECTRICITY GENERATED FROM RENEWABLE ENERGY SOURCES

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Abstract:

The most important step in the modern era is the distribution and management of electricity using artificial intelligence, particularly energy generated from renewable energy sources. This ensures the sustainability of energy sources and thus improves the efficiency of electrical grids. There are many challenges facing the renewable energy sector, resulting from fluctuations in production, climate disturbances, and imbalances in supply and demand. Artificial intelligence can help solve these challenges. Using machine learning techniques, environmental forecasting, and efficient management of these resources can improve the accuracy of forecasting production levels from solar and wind energy. Smart grids are among the most prominent applications in this field because they represent a model for artificial intelligence applications, which rely on improving energy distribution among consumers based on their actual needs, thus increasing efficiency and reducing losses. It can also optimize storage systems by determining optimal charging and discharging times for stored energy, reducing the need for massive infrastructure investments. The need for advanced security solutions has emerged due to the presence of security threats related to cyberattacks on smart grids. However, related challenges include high investment costs and the need for accurate and reliable data from various operating environments. However, the future is moving toward integrating artificial intelligence into renewable energy management. This will be the ideal solution for addressing issues of improving energy production and storage, thereby enhancing grid efficiency and making them more flexible, meeting energy needs, and achieving global sustainability and clean energy goals.

Keyword: Artificial Intelligence, Renewable Energy, Energy Management, Energy Sustainability, Smart Grid Security.

Introduction

Photovoltaic energy is considered one of the most important renewable energy sources [1], and it is increasingly important in achieving sustainable development goals due to its renewable, clean, and environmentally friendly nature. It is now used in many industrial fields, and artificial intelligence (AI) has become an essential tool for managing and distributing electricity generated from renewable energy sources and storing and utilizing it during peak times or power outages [18]. It has become a vital tool for improving operational efficiency and enhancing the sustainability of renewable energy systems in light of global trends in many industrial fields, most notably the management, and distribution of energy generated from renewable sources, most notably solar and wind energy, through production forecasting, improved network management, and balancing supply and demand (IEA, 2021) [5]. AI also provides opportunities to improve the efficiency of intelligent systems, reduce losses, and promote optimal energy distribution (IEEE, 2020) [1]. AI in renewable energy also improves the ability and flexibility of networks to respond to climate fluctuations that affect solar and wind energy production (World Economic Forum, 2020)[4], achieves better distribution, reduces costs, and increases efficiency, which supports reducing dependence on fossil fuels (IEEFA, 2021)[7].

1-2 Artificial Intelligence in Renewable Energy Management and Distribution.

A. Definition of Artificial Intelligence (AI):

A field of computer science used to develop intelligent systems and make energy-related decisions by simulating human mental capabilities through reasoning techniques, machine learning, neural network technology, and decision-making algorithms to improve energy management and distribution (IEEE, 2020)[1].

B. Energy and Grid Management:

Accurately predicting future solar and wind energy production, dynamically calculating the amount of energy generated and flowing into the grid, identifying peak times, and adjusting energy flows (Liu, 2020)[6] improves energy management, optimally distributing and storing energy flexibly through predictive control (IEEE, 2020)[1]. It also manages the electrical grid more effectively and enhances efficiency by reducing losses and stabilizing the electrical grid (International Energy Agency, 2021)[5].

C. Smart Grid Management:

Flexibly and efficiently managing the flow of electricity across the smart grid. By adapting to changes in production and consumption, thus reducing electricity and losses and increasing efficiency.

1-3 Challenges Facing Artificial Intelligence in Renewable Energy Management

A. Technical Challenges:

Technical challenges, such as climate variability, are the biggest obstacles that make it difficult to accurately predict energy production under changing weather conditions, potentially leading to a mismatch between supply and demand (IEEFA, 2021)[7].

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B. Implementation Cost Challenges:
The high cost of integrating smart systems is one of the most significant challenges, due to the need for advanced technology to analyze big data and trained teams (IEA, 2021)[5].

C. Privacy and Cybersecurity Challenges:
Due to the reliance on big, live, and real data and the need to analyze it, it is essential to take concrete measures to protect networks from cyberattacks. (World Economic Forum, 2020)[4].

D. Data and its Quality:
AI applications rely on the quality of the data they obtain, which is accurate and represents real-time environmental conditions to accurately manage production and distribution.

1-4 practical applications of artificial intelligence in renewable energy management and distribution on the ground:

A- Solar energy management in Germany:
AI was used to study, analyses, and improve climate data, and to organize storage and distribution. https://new.siemens. com

B- California Department of Energy:
Improving energy distribution and efficiency, particularly for solar and wind energy, was achieved through the use of artificial intelligence. https://www.ge.com

C- Predictive techniques:
Neural networks and algorithms predicted production levels and improved energy management. https://www.tesla.com

D- Demand management capabilities:
AI was used to determine the actual energy needs of consumers based on available data and forecasts.

1-5 Literature Reviews :
Significant progress has been made in the exploitation and management of renewable energy resources through artificial intelligence, which can, therefore, be considered an essential part of achieving increased accuracy, reliability, efficiency, energy storage, smart grids, and routine maintenance management, all of which we will explore in this review.
In 2020, Zhang et al. discussed in a comprehensive review the prediction of energy generated from renewable sources (solar and wind) and the necessity of using machine learning, represented by neural networks, algorithms, and stochastic regression, which provided prediction accuracy of up to 95%.

In 2021 the researcher presented a comprehensive review of smart grids and their management. Artificial intelligence algorithms improved the stability and response of electrical grids, thus reducing losses.

In 2022, a study presented by Siemens Research, 2023, and Basim J demonstrated the integration process of integrating renewable energy into the electrical grid and improving it through machine learning algorithms, reducing dependence on traditional plants.

In 2022, Luo et al., 2023, Basim J. worked on improving batteries, improving their control, and reducing losses.

In 2023, Kim et al. (2023) The study demonstrated the need to use machine learning in predictive maintenance to prevent damage, errors, and breakdowns before they occur, as it contributed to reducing the rate of breakdowns by 35%.

Also, in 2023, the study conducted by B. Jabbar (2023) showed the necessity of using a machine learning algorithm to predict and monitor the generated energy.

In the same year, 2023, a report submitted by the IEA demonstrated the need to promote the use of renewable energy. This has significantly contributed to reducing pollution and carbon emissions, which have decreased by a very high percentage, exceeding 40%, due to the application of artificial intelligence in energy management.

1-6 Proposed Design:

1-6-1 Designing an AI-Powered Management System:

To achieve optimal sustainability and the highest efficiency of the electrical system, an AI-powered energy management system was designed to optimize energy distribution and storage through prediction, fault handling, and proactive predictive maintenance. The system consists of:

A. Data Analysis (Energy Generation and Production):
   This system analyses and processes data using neural networks and machine learning techniques to identify appropriate patterns. This data can be integrated with the internet to monitor weather conditions and seasonal fluctuations. This technology provides an accuracy rate exceeding 95%.

B. Balancing Demand and Distribution:
   Smart grid control helps improve grid stability and reduce losses. This is achieved by balancing demand between conventional and renewable energy using control algorithms.

C. Storage Management:
   To reduce thermal stress and control the charging and discharging process and timing, thus protecting batteries from damage.

D. Predictive Maintenance.
   To reduce potential failures and errors, and thus reduce maintenance costs, data from sensors installed on the network is analyzed using artificial intelligence. This process reduced the occurrence of failures by 35%.

1-6-2 Practical Implementation:

A. Tools and programs:

Network simulation and analysis using MATLAB.

B. Data Collection:

Data related to production, distribution, and storage is collected through sensors connected to the system and network.

C. Data Processing:

The collected data is sent to analytics platforms for analysis.

D. Artificial Intelligence Application:

Algorithms are trained on the data for prediction.

E. Testing:

Using MATLAB simulations for testing before real-world implementation.

F. Evaluation:

Periodic evaluations are conducted regarding (efficiency, production, distribution, storage, losses, maintenance, and failure reduction).

G. Results:

The table below shows the results obtained.

1-6-3 Real-world implementation steps:

- The possibility of successfully implementing the system on the ground without any problems or errors.
- Gradual implementation to achieve realistic results.
- Simulate and test the work environment.
- Simulate the smart grid and evaluate its operation and performance.
- Simulate the experimental renewable energy system.
- Using machine learning algorithm data for predictive reasoning.
- Test the operation of sensor code and artificial intelligence and display the results and differences.
- Improvement of work and production forecasting, storage management, and maintenance.
- The possibility of gradual expansion to include larger projects on the ground.
- Energy sources can be diversified and networks can be controlled.

1-6-4 private programming code:

```
click; clear; close all;
%% Definition of basic parameters
Generated = landscape (0, 100, 100); % Power produced (0 to 100 kW)
load variation = sin (landscape (0, 2*pi, 100)) * 10 + 50; % Load variation (kW)

%% Efficiency and loss calculations
losses traditional = 0.2 * Generated; % 20% losses in a conventional system
losses = 0.1 * Generated; % 10% losses in a smart system
efficiency traditional = (Generated - losses traditional). /Generated * 100;
efficiency = (Generated - losses). /Generated * 100;
%% Plotting results
figure;
subplot (2,2,1);
plot (Generated, efficiency traditional, 'r', 'Linewidth', 2); hold on;
plot (Generated, efficiency, 'b', 'Linewidth', 2);
label ('Power Produced (kW)'); label ('Efficiency (%)');
legend ('Conventional', 'AI'); title ('Efficiency Comparison'); grid on;

subplot (2, 2, 2);
plot (Generated, losses traditional, 'r', 'Linewidth', 2); hold on;
plot (Generated, losses, 'b', 'Linewidth', 2);
label ('Power Produced (kW)'); label ('Losses (kW)');
legend ('Conventional', 'AI'); title ('Losses Comparison'); grid on;
subplot (2,2,3);
plot (Generated, load variation, 'g', 'Linewidth', 2);
label('Time'); label ('Load Variation (kW)');
title ('System Response to Load Variations'); grid on;
subplot (2,2,4);
efficiency gain = efficiency - efficiency traditional;
plot (Generated, efficiency gain, 'm', 'Linewidth', 2);
label ('Power Produced (kW)'); label ('Efficiency Improvement (%)');
title ('Efficiency Improvement Using Artificial Intelligence'); grid on;
```

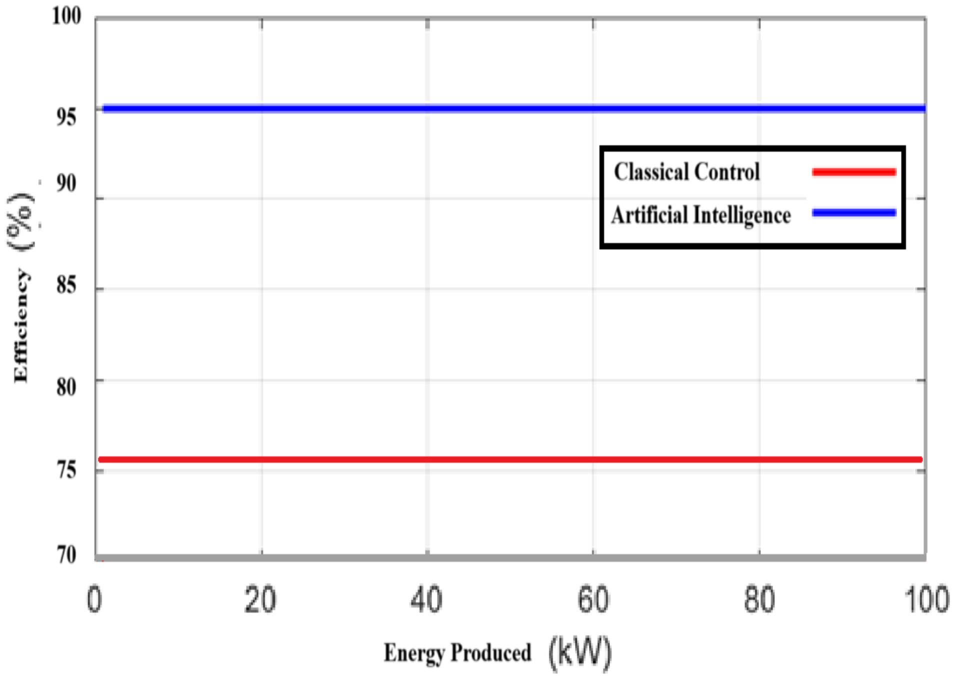

Figure (1) Efficiency of the conventional system and artificial intelligence

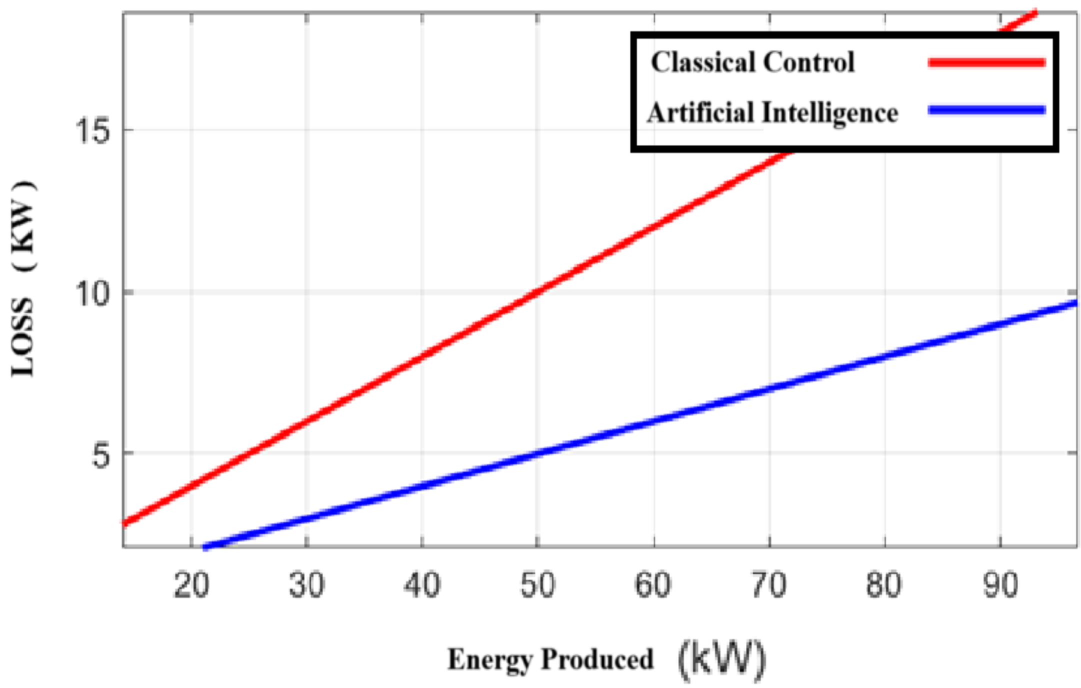

Figure (2) Losses of the conventional system and artificial intelligence

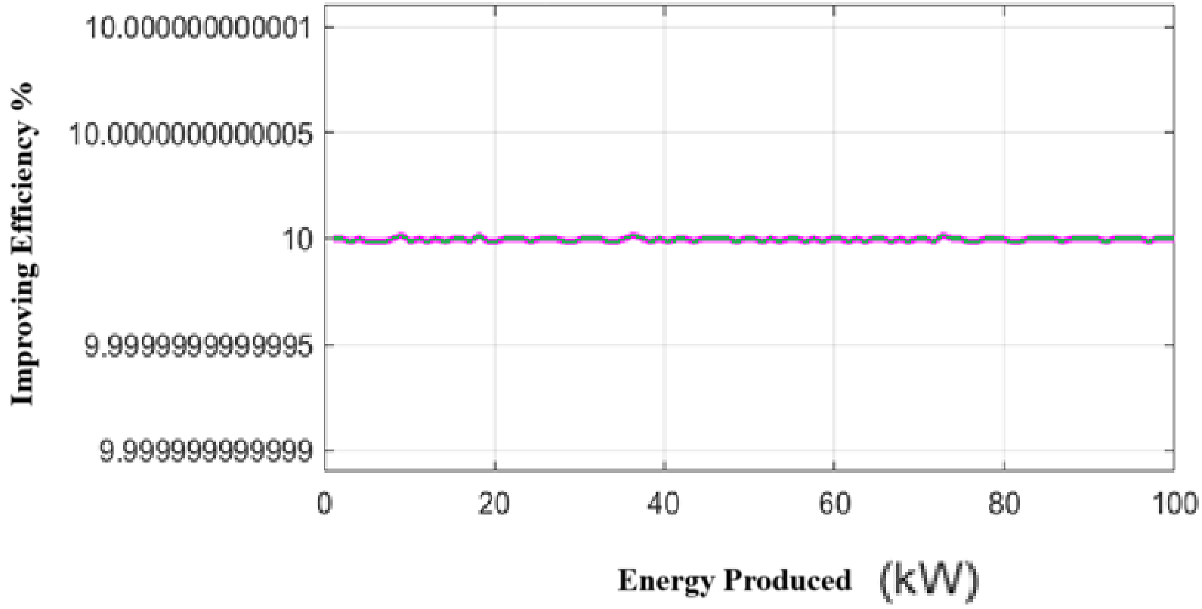

Figure (3) Improvements in the use of artificial intelligence

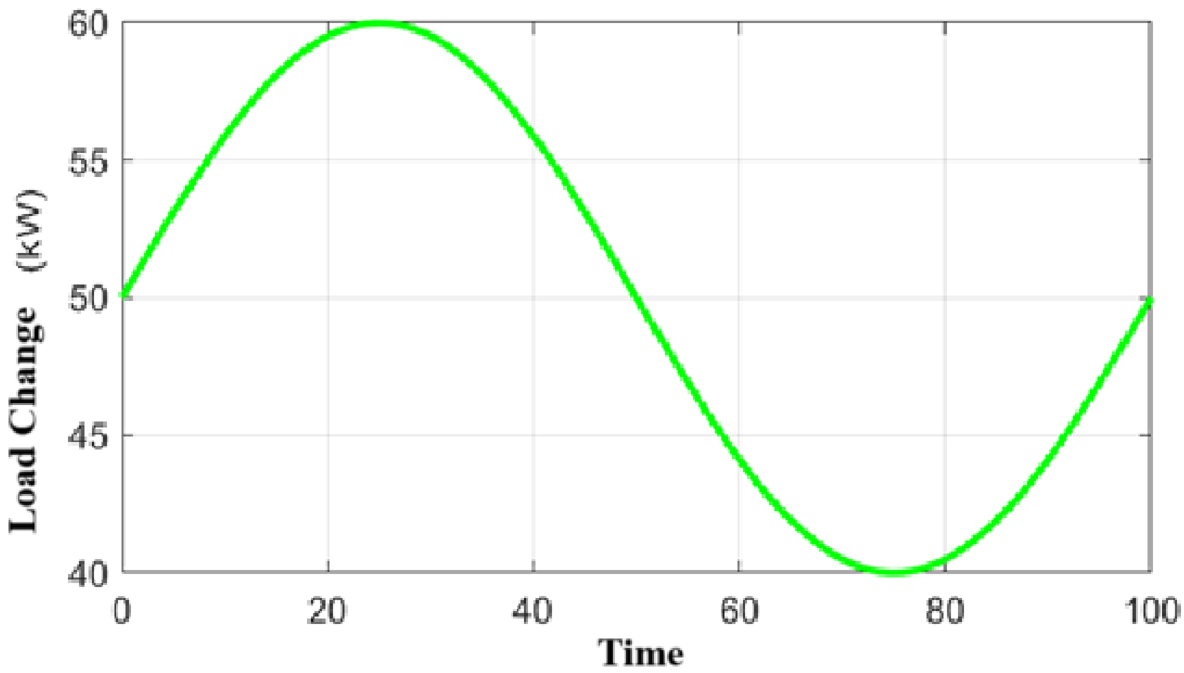

Figure (4) System response to load changes

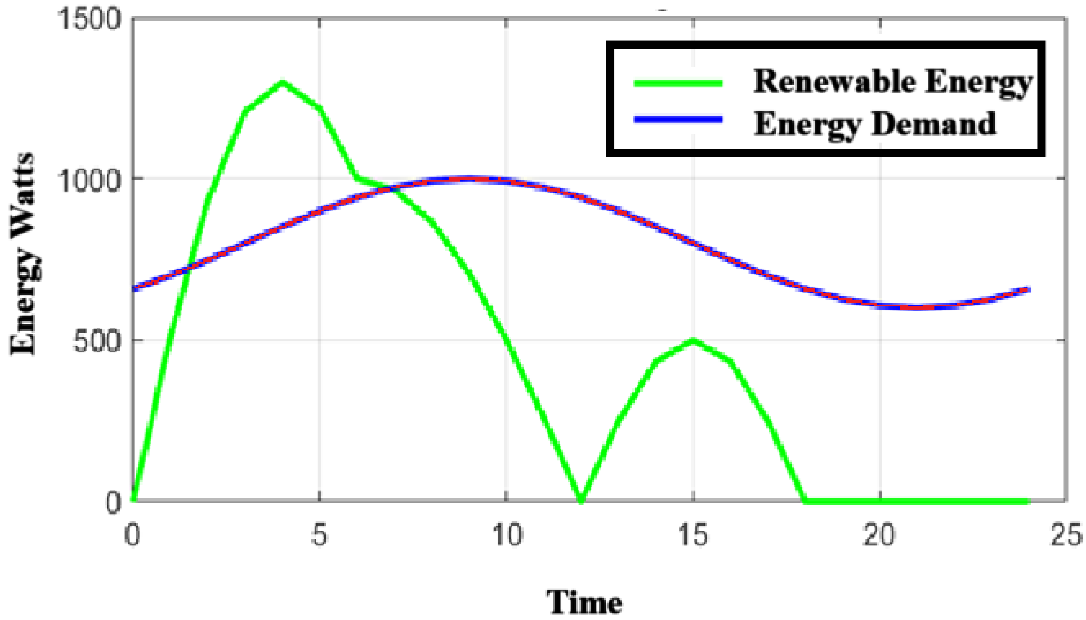

Figure (5) Energy production and demand.

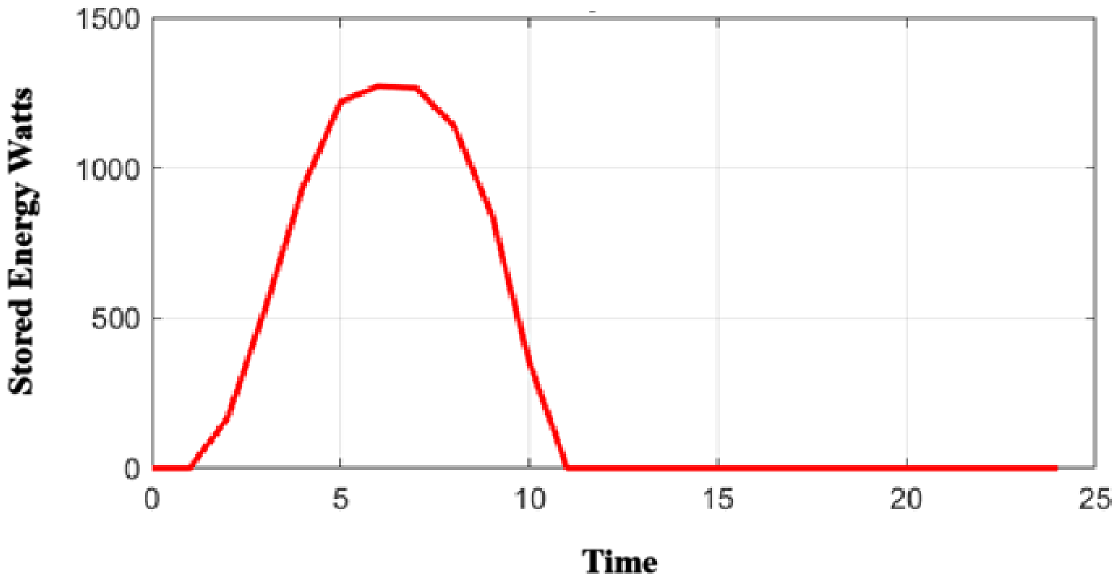

Figure (6) Energy stored in batteries.

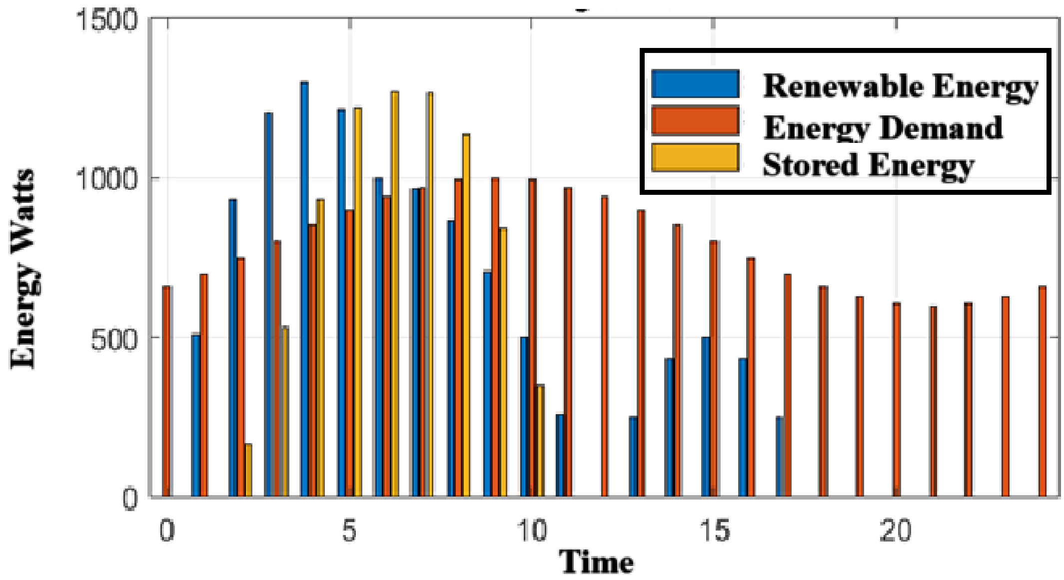

Figure (7) Energy distribution comparison.

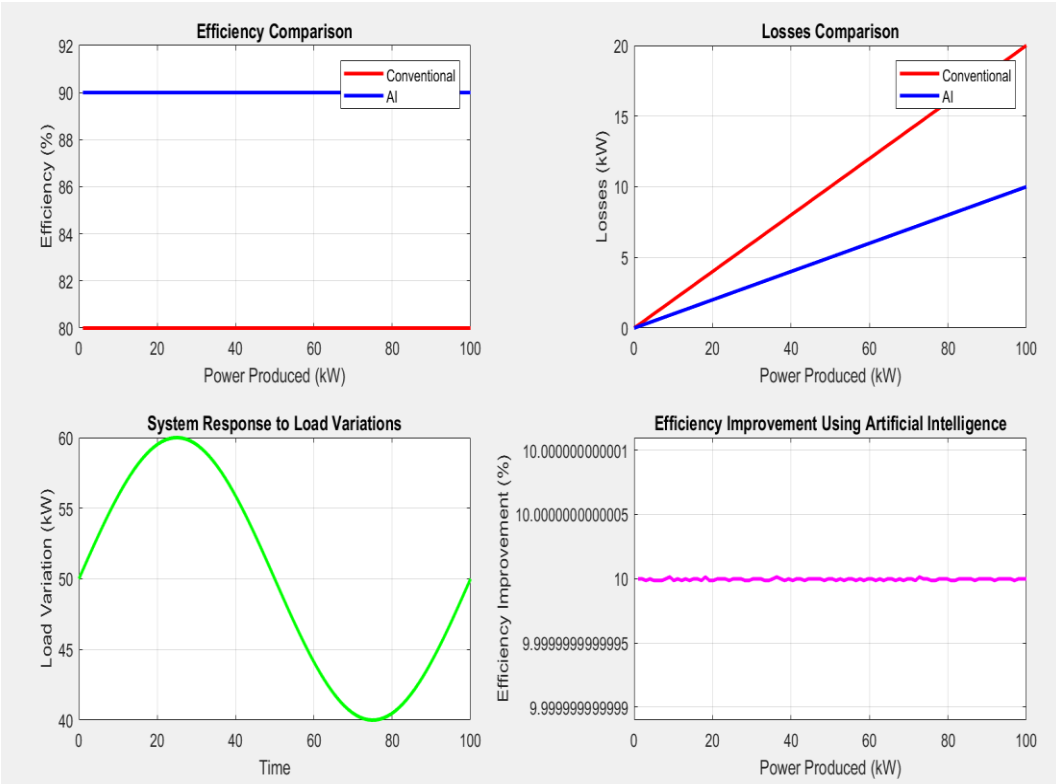

Figure (8) Summary of the power management code.

Table (1) shows the results and the difference between the traditional and proposed systems.

No.	Traditional	Traditional research system		Proposed AI-Based System
1	Distribution efficiency:	Wang et al., 2021	75%	95%
2	Production forecast accuracy	Zhang et al., 2020	60 -70%	90 -95%
3	Stored energy utilization	Luo et al., 2022	65%	85%
4	Battery lifespan improvement	Luo et al., 2022	Not supported	30% increase
5	breakdowns and maintenance	Kim et al., 2023	High	Low: 35%
6	Energy loss during transmission	IEA, 2021	8-12%	5-7%
7	Carbon emissions reduction	IEA, 2023	Not effective	40% reduction
8	Grid integration with RES	Siemens Research, 2022	Normal connection	Improved integration
9	Transmission Energy Losses in Smart Grids	Wang et al., 2021	Improvements of up to 10%	15% Improvement
10	Dynamic Energy Distribution	Reza Z.2023	Conventional Data	Speed Demand Analysis and Increasing Transmission Efficiency
11	Responding to Changes		Slow Response	Immediate Response

1-9 Global Applications of Artificial Intelligence:

Google's DeepMind & UK National Grid: Reducing Waste by Predicting Energy Consumption.

Tesla - Powerwall & Powerpack: Optimizing Energy Management and Storage and Increasing Battery Efficiency.

Siemens & AI Smart Grids: Analyzing and Optimizing Grid Performance

Discussion

Through this research, it is evident that significant improvements can be made in renewable energy management when compared to traditional control methods. Studies have shown that artificial intelligence control has increased energy efficiency and storage, reduced losses, and significantly improved the stability of smart grids. To ensure the integration of these technologies with energy generation and distribution sources, and because the cost and the need for advanced infrastructure are the primary obstacles to the implementation of artificial intelligence, there is a need to adopt regulatory policies compatible with the requirements of the smart operation.

Conclusions

Through the research, it was found that the potential for improving energy generation, grid stability, and forecasting through artificial intelligence compared to traditional control methods is:

A. Improving efficiency and reducing losses.

B. Enhancing system continuity through predictive maintenance.

C. Improving battery and storage management and stabilizing smart grids.

D. Integrating energy sources and the grid through advanced management.

Recommendations :

Support and enhance future scientific and practical research in energy management using artificial intelligence.

Evaluate the performance of artificial intelligence systems through field-based experimental applications for renewable energy management.

Regulate laws and regulations to allow for the integration of renewable energy systems and grids with artificial intelligence.

For effective and sustainable implementation, engineers and technicians must be trained in energy and artificial intelligence.

Open the door to the private sector and investors and integrate them with other sectors.

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