

# Review of AI Applications in Electrical Engineering: A Decade of Progress and Innovation

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#### Abstract:

Artificial Intelligence (AI) has revolutionized multiple sectors, and its application in Electrical Engineering has gained significant momentum over the past decade. This review explores the various applications of AI within the field of Electrical Engineering, focusing on research advancements from the last ten years. From power systems to robotics, AI technologies such as machine learning, deep learning, and optimization algorithms have been leveraged to address complex challenges, enhance system performance, and improve efficiency. This paper outlines key trends, methodologies, and future directions of AI applications in electrical engineering.

Keyword: Artificial Intelligence (AI), Electrical Engineering

## 1. Introduction

Over the last decade, AI has transcended traditional boundaries computational and found diverse applications in Electrical Engineering (EE). As EE is pivotal in industries like energy, automation, telecommunications, and transportation, AI has introduced innovative ways to optimize processes, improve system reliability, and reduce operational costs. This review seeks to summarize the major AIdriven breakthroughs in EE, based on research and development (R&D) trends in the last ten years. We analyze applications in power systems, electrical machines, renewable energy, and automation, drawing insights into the evolving role of AI.

## 1) AI in Power Systems

One of the primary areas where AI has shown significant promise is in the optimization and management of power systems. Traditional power grids are evolving into "smart grids," which utilize advanced technologies such as IoT and AI to improve reliability, efficiency, and sustainability. A key trend observed over the past decade is the application of machine learning (ML) for load forecasting, fault detection, and predictive maintenance in power grids.

1. Load Forecasting and Demand Response: Machine learning algorithms such as support vector machines (SVM) and deep neural networks (DNN) are increasingly being used to predict electricity demand more accurately. Research by Zhang et al. (2018) has demonstrated that AI-based models significantly outperform traditional statistical methods in predicting power load for smart grids, helping utilities adjust their supply accordingly.

2. Fault Detection and Diagnosis: AI techniques like decision trees, random forests, and reinforcement learning have been applied to enhance fault detection and classification in power systems. For example, the work of Wang et al. (2019) uses deep learning to analyze real-time sensor data from substations, enabling the early detection of faults and minimizing downtime in power distribution systems.



3. Predictive Maintenance: AI-driven predictive maintenance is widely used to monitor the condition of electrical equipment such as transformers and circuit breakers. Research by Liu et al. (2021) highlights the use of AI-based algorithms to predict equipment failures, thereby reducing unplanned outages and improving the lifespan of components.

## 2) AI in Electrical Machines and Automation:

AI technologies are also gaining traction in the design, optimization, and control of electrical machines and industrial automation systems. The advent of smart manufacturing, combined with AI, has brought about innovations in motor control, robotics, and production efficiency.

1. Motor Control: Machine learning models are being applied to improve motor performance in terms of efficiency, fault detection, and control optimization. For instance, reinforcement learning is used for the real-time control of electric motors in industrial applications, optimizing speed and torque in a dynamic environment (Chen et al., 2020).

2. Robotics and Automation: AI has transformed industrial robotics, allowing for intelligent decisionmaking in real-time. In the last decade, the integration of AI with programmable logic controllers (PLCs) has facilitated autonomous robotic systems capable of performing complex tasks in environments where human intervention is either inefficient or dangerous. Research by Kormushev et al. (2013) on robot learning and control algorithms continues to inform innovations in manufacturing automation, reducing human labor costs while increasing precision.

### 3) AI in Renewable Energy Systems:

AI plays a crucial role in advancing renewable energy technologies, particularly in the optimization of energy production and integration into the grid. Solar, wind, and energy storage systems have benefitted from AI's ability to forecast renewable energy generation and optimize the use of storage systems.

1. Solar Power Optimization: AI has significantly contributed to maximizing the efficiency of

photovoltaic (PV) systems. Research by Kumar et al. (2019) demonstrates the use of deep learning to predict solar power output based on weather conditions, thus enabling better grid integration and reducing reliance on non-renewable power sources.

2. Wind Energy Forecasting: Machine learning techniques, including ensemble models, are applied for wind energy forecasting to better manage wind turbine operations. A study by Zhao et al. (2020) shows how AI models can predict wind speed and power output with higher accuracy, thereby optimizing the control of turbines and integrating wind energy into the grid.

3. Energy Storage and Grid Management: The integration of AI with energy storage systems has improved the efficiency of energy dispatch. AI algorithms can predict energy storage demand, manage battery cycles, and optimize charging and discharging processes. Research by Zhang et al. (2022) highlights the application of AI for real-time monitoring of battery performance, enhancing the lifespan of energy storage systems.

### 4) AI in Smart Transportation Systems:

Another key area where AI has made an impact is in smart transportation systems, particularly in electric vehicles (EVs) and traffic management. Over the last decade, AI has been employed to optimize energy usage in EVs, improve charging infrastructure, and enhance traffic control systems.

1. Electric Vehicles and Charging Optimization: AI has been leveraged to optimize battery management systems in EVs. Deep learning algorithms help predict battery life and performance, while reinforcement learning is used to optimize charging stations and vehicle charging schedules, as explored by Liu et al. (2021).

2. Traffic Management: AI-powered traffic management systems use real-time data to optimize traffic flows, reduce congestion, and lower energy consumption. Neural networks and genetic algorithms are increasingly being used to develop intelligent traffic lights and routing algorithms that adapt to



changing conditions, as demonstrated in research by Zhang and Zhao (2019).

#### 2. Challenges and Future Directions:

While the progress made in applying AI to Electrical Engineering has been remarkable, several challenges remain. These include data quality and availability, the need for high computational power, integration with legacy systems, and the lack of standardized AI models. The future of AI in EE will likely focus on enhancing explainability, transparency, and adaptability of AI models, as well as integrating AI with emerging technologies such as blockchain for secure and efficient power system management.

Future research will continue to explore the intersection of AI and quantum computing, exploring how quantum algorithms could further enhance the computational efficiency of AI models in electrical systems. The development of federated learning models for decentralized data processing in smart grids and the integration of AI with 5G communication networks for enhanced IoT applications are also areas of growing interest.

### 3. Conclusion:

In the last decade, AI has made significant strides in Electrical Engineering, transforming industries ranging from power systems and renewable energy to automation and smart transportation. Through the integration of machine learning, deep learning, and optimization algorithms, AI has brought about innovations that promise to improve the efficiency, reliability, and sustainability of electrical systems. As AI technology continues to evolve, its role in Electrical Engineering is expected to grow even more, presenting exciting opportunities for further advancements in the field.

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