

# Electrical Engineering and Intelligent Control Strategies in Renewable Energy Integration: Enhancing Energy Sustainability

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**Abstract:** *This paper discusses in detail the important role and application value of electrical engineering and intelligent control strategies in the integration of renewable energy, and proposes the viewpoints of improving the utilization rate of renewable energy and ensuring the stability of energy systems through electrical engineering and intelligent control strategies. At the same time, it also looks forward to the future development trend.*

**Keywords:** electrical engineering; intelligent control strategy; renewable energy; energy storage; grid access; power electronics technology; energy transformation; automated control.

## 1. INTRODUCTION

### 1.1 Research Background

As global environmental problems and the greenhouse effect become increasingly serious, the development and utilization of renewable energy has become an important direction for global energy transformation. In terms of reducing greenhouse gas emissions, protecting the ecological environment, and promoting sustainable development, renewable energy, including wind energy, solar energy, geothermal energy, biomass energy, etc., has the characteristics of cleanliness, low carbon, and renewable, and has played an important role.

Electrical engineering and intelligent control strategies play an important role in the field of renewable energy. The development and utilization of renewable energy requires the support of an efficient and reliable power system, and the key technology for building such a power system is precisely electrical engineering. At the same time, renewable energy has the characteristics of unstable and uncontrollable power generation. In order to achieve efficient management and optimal utilization of energy, intelligent control strategies are needed.

### 1.2 Research purposes

This paper aims to conduct an in-depth discussion on the role and value of electrical engineering and intelligent control strategies in renewable energy integration. The development and utilization of renewable energy has become an important direction for energy transformation in various countries. Renewable energy generation has the characteristics of instability and uncontrollability, which also brings challenges to the operation and management of power systems. Therefore, this paper aims to provide theoretical support and practical guidance for promoting energy transformation and sustainable development through the study of electrical engineering and intelligent control strategies in renewable energy integration.

This paper will focus on the following aspects: First, analyze the characteristics and challenges of renewable energy power generation, and explore the role of electrical engineering and intelligent control strategies in solving the unstable and uncontrollable problems of renewable energy power generation; second, study the application of electrical engineering and intelligent control strategies in renewable energy power transmission and distribution, power electronic equipment, energy storage technology, etc., to improve the utilization efficiency of renewable energy; third, explore the application of electrical engineering and intelligent control strategies in renewable energy power generation prediction, optimal scheduling, status monitoring, fault diagnosis, etc., to achieve efficient management and optimal allocation of energy.

### 1.3 Significance

First of all, this research is of great significance to enhancing the sustainable use of energy, promoting the

development of clean energy, and reducing environmental pollution. In the use of renewable energy, the study and application of electrical engineering and intelligent control strategies can improve the utilization efficiency of renewable energy and optimize the energy structure, thus providing a guarantee for promoting long-term energy security.

Secondly, promoting the use of clean energy is an effective means to reduce greenhouse gas emissions and address climate change. The development of electrical engineering has promoted the efficient conversion and utilization of clean energy, and intelligent control strategies can improve the flexibility and response speed of energy systems while being able to manage energy in a refined manner, reduce carbon emissions and other environmental pollutants, and thus play an important role in promoting global climate governance and environmental protection. Then, the development of electrical engineering and intelligent control technology provides technical support for promoting the scale and commercialization of renewable energy. Taking the construction of smart grids and the innovation of energy storage technology as an example, the connection between renewable energy generation and traditional power systems has greatly improved the stability and reliability of the system; it also solves the intermittent problem of renewable energy and enhances the continuity and quality of power supply. While promoting the development of the clean energy industry, it also provides a strong impetus for the green transformation of the social economy.

Finally, this study is of great significance to promoting energy technology innovation and industrial upgrading. With the development of electrical engineering and intelligent control technology, a large number of new products and services have been created, which has brought revolutionary changes in the energy field and created new opportunities for the development of related industries.

#### **1.4 Research content**

This study deeply explores the key role of electrical engineering in the integration of renewable energy and the efficient application of intelligent control strategies in renewable energy systems, and introduces and analyzes the key role of electrical engineering in renewable energy systems.

In the field of electrical engineering, the basic principles and characteristics of various renewable energy power generation systems are introduced, including solar energy, wind energy, geothermal energy, etc. In addition, the key role of power electronics technology in renewable energy systems, including its development trends and application prospects, is studied.

In terms of intelligent control strategies, the basic principles of intelligent control technology are outlined, and its optimization strategies in wind-solar hybrid systems and energy storage systems are discussed.

Finally, this study summarized the research results and looked forward to the future development direction and challenges of electrical engineering and intelligent control strategies in renewable energy integration. It is believed that with the continuous advancement and innovative development of science and technology, electrical engineering and intelligent control strategies will play an increasingly important role in promoting renewable energy integration, and make greater contributions to promoting the optimization of my country's energy structure and achieving sustainable development.

## **2. APPLICATION OF ELECTRICAL ENGINEERING IN RENEWABLE ENERGY INTEGRATION**

### **2.1 Renewable energy power generation system**

Renewable energy generation system refers to a system that uses renewable energy in nature to produce electricity. It mainly includes:

1. Wind power generation system uses wind power to drive turbines to rotate and generate electricity through generators. Its characteristics are that it does not require fuel and does not produce greenhouse gas and pollutant emissions, but it is greatly affected by wind speed and wind direction, and power generation is unstable.
2. Photovoltaic power generation system uses sunlight to shine on photovoltaic panels to generate electricity. Its characteristics are that it does not require fuel and has no emissions. It is suitable for use in areas with abundant

sunshine, but it is greatly affected by weather and nighttime, and power generation is unstable.

3. The hydroelectric power generation system uses the power of water flow to drive the turbine to rotate and generate electricity through the generator. Its characteristics are strong dispatchability and stable power generation, but it is greatly restricted by geographical location and water resources.

4. Biomass power generation system uses biomass energy to generate electricity, such as agricultural waste, urban garbage, etc. Its characteristics are that it can be recycled and reduce garbage pollution, but it is greatly restricted by fuel supply and combustion emissions.

5. Geothermal power generation system uses the heat energy inside the earth's crust to generate electricity. It is stable and reliable, and is not affected by weather and seasons, but is greatly restricted by geographical conditions.

## 2.2 Grid access technology

Electrical engineering plays a vital role in the integration of renewable energy into the grid, but it also faces a series of key technologies and challenges. The following is a discussion of these technologies and challenges:

First of all, the key technologies of electrical engineering in renewable energy grid connection include grid connection technology, power electronics technology, power quality control technology, etc. Grid connection technology involves the connection method between renewable energy power generation system and grid, interface standard, voltage and frequency regulation, etc., to ensure the smooth transmission and distribution of electric energy. Power electronics technology includes the application of equipment such as converters and inverters, which are used to convert the DC power generated by renewable energy power generation system into AC power. Power quality control technology is used to solve the power quality and stability problems of renewable energy power generation system such as voltage fluctuation and current harmonics.

Secondly, the challenges faced by electrical engineering in the grid connection of renewable energy mainly include: the instability and uncontrollability of renewable energy generation, the adaptability and regulation capacity of the power grid, the reliability and safety of the system, etc. Renewable energy generation is generally greatly affected by weather and environmental factors, and is unstable and uncontrollable, which brings challenges to the operation and management of the power grid. The power grid needs to have sufficient adaptability and regulation capabilities to cope with the volatility and intermittency of renewable energy generation. At the same time, the reliability and safety of the system are also important considerations. It is necessary to ensure that the access of renewable energy generation systems will not cause excessive impact and risks to the power grid.

Finally, in the connection of renewable energy to the grid, electrical engineering also involves the planning and management of the grid. With the scale of renewable energy generation, the grid needs to be adjusted and planned accordingly to accommodate the increasing number of renewable energy generation systems, while also ensuring the effectiveness and efficiency of the operation and management of the grid, and establishing a control and protection mechanism that is compatible with it.

## 2.3 Power Electronics Technology

An important role in renewable energy systems. Power electronics technology mainly involves the design, manufacture and application of power electronic devices and equipment for efficient conversion and control of electrical energy. The core role of power electronics technology in renewable energy systems is reflected in:

1. Power conversion of renewable energy power generation systems: Power electronics technology can convert the DC power generated by renewable energy power generation systems into AC power to meet the requirements of the power grid.

2. Power quality control: Apply power electronics technology to optimize the power quality of renewable energy power generation systems, such as reducing voltage and current fluctuations, reducing harmonics, etc., to improve the stability and quality of power.

3. System adjustment and optimization: Use power electronics to adjust and optimize the output of renewable energy generation systems to adapt to the needs and changes of the power grid, such as adjusting the output voltage

and frequency of the inverter to achieve the purpose of stable support and regulation of the power grid.

With the development and progress of renewable energy systems, the development of power electronics technology has also seen several challenges and development directions:

1. High efficiency and reliability: In order to cope with the increasingly severe energy consumption situation , research and development of efficient and reliable power electronic technologies and devices has become an important development direction.
2. System integration and intelligence: In order to improve the intelligence level and overall performance of renewable energy systems, power electronics must be integrated with other related technologies based on the combination of modern control theory and modern communication technology.
3. Cost and scale: To promote the widespread use of renewable energy, improving the level of power electronics technology and reducing related costs and promoting large-scale production are inseparable.

### **3. APPLICATION OF INTELLIGENT CONTROL STRATEGIES IN RENEWABLE ENERGY SYSTEMS**

#### **3.1 Overview of Intelligent Control Technology**

so-called intelligent control technology in renewable energy systems is to use advanced technologies including artificial intelligence fuzzy logic neural network expert systems to monitor, analyze, make decisions and optimize complex systems in real time on the basis of intelligent control strategies, so that the automation and intelligence level of the system has been greatly improved. It plays a very important role in improving energy utilization efficiency , ensuring energy security and promoting sustainable development. The basic principles of intelligent control technology for renewable energy systems are mainly the following aspects:

1. Real-time monitoring: The intelligent control system can obtain and monitor the operating data and status information of the energy system in real time through various sensors and monitoring instruments, such as the measurement of voltage, current, temperature, pressure, etc. , so that the system can monitor the energy system's performance. Real-time monitoring of operating status.
2. Data processing and analysis: Use intelligent control systems to analyze and process the massive data collected, extract useful information to identify and diagnose abnormalities and faults in the system , and significantly improve the operating efficiency of the system.
3. Decision-making and optimization: The intelligent control system of the energy system makes decisions and optimizes it through result analysis , so that the system can be adjusted and adjusted while improving energy utilization efficiency and ensuring stable operation of the system.

At present , intelligent control technology has been widely used in energy systems.

1. Renewable energy system: By applying intelligent control technology , the renewable energy power generation system is optimized for scheduling , fault diagnosis , predictive maintenance, etc., which improves the utilization efficiency of renewable energy and also has a positive impact on energy transformation.
2. Power system: With the help of intelligent control technology, it can realize functions such as load forecasting and fault handling, and make an indelible contribution to improving the stability and reliability of the power system.
3. Energy management system: In the monitoring, analysis and optimization of energy consumption, the application of intelligent control technology can realize real-time monitoring and prediction of energy consumption, so that energy consumption can be effectively controlled and optimized.

#### **3.2 Application of intelligent control in wind-solar hybrid system**

The optimization strategy of intelligent control in the complementary system of wind power generation and

photovoltaic power generation is an important technology, because the power generation characteristics of these two renewable energy sources are complementary, that is, wind power generation usually generates more electricity at night or during periods of high wind speed, while photovoltaic power generation generates more electricity during periods of abundant sunshine during the day. Therefore, through intelligent control technology, these two power generation methods can be effectively coordinated to achieve the purpose of optimizing scheduling and improving the overall efficiency of the system. The optimization strategy in the complementary system of wind power generation and photovoltaic power generation based on intelligent control mainly includes the following main aspects:

1. Prediction and forecast: Intelligent control systems can use meteorological data and historical power generation data to predict and forecast the output of wind power generation and photovoltaic power generation, so as to better formulate power generation plans, achieve the purpose of optimized scheduling, and obtain more accurate results through prediction.
2. Real-time monitoring and adjustment: The intelligent control system monitors the operating status of wind power generation and photovoltaic power generation in real time, comprehensively compares the actual power generation with the load demand, and makes real-time adjustments and optimizations accordingly to achieve the best energy utilization effect.
3. Coordination of energy storage system: The intelligent control system can work in coordination with the energy storage system to store excess electrical energy, balance the volatility of wind power generation and photovoltaic power generation, and improve the reliability and stability of the system.
4. Multi-energy complementarity and optimization: Intelligent control systems can integrate and optimize wind turbines and photovoltaic generators with other energy systems, and achieve optimal energy utilization efficiency through multi-energy complementarity, such as demand response of power grid energy storage systems, etc., and realize multi-energy complementarity and optimization through intelligent control systems.

### **3.3 Application of intelligent control in energy storage systems**

In the process of integrating renewable energy, intelligent control in the scheduling and optimization strategy of energy storage systems is a very important technology. Since the role of energy storage systems is to help balance the volatility of renewable energy and improve the stability and reliability of energy supply, it is of great significance ; based on intelligent control technology, it can effectively schedule and optimize energy storage systems to achieve maximum energy utilization efficiency and economic benefits. The scheduling optimization strategy of energy storage systems based on intelligent control mainly includes the following main aspects :

1. Real-time monitoring and prediction: The intelligent control system monitors the operating status of the energy storage system in real time, conducts a comprehensive assessment of the battery charging and discharging status, conducts a comprehensive assessment of various parameters of the energy storage system, and conducts a comprehensive analysis of historical data and meteorological data, thereby predicting the power generation and load demand of renewable energy, and providing accurate data to support scheduling and optimization.
2. Scheduling and optimization algorithms: In order to maximize economic and environmental benefits, intelligent control systems can use advanced scheduling and optimization algorithms, such as dynamic programming and genetic algorithms, to formulate optimal charging and discharging strategies based on real-time monitoring and forecasting data. These algorithms consider factors such as electricity prices , load demand, and renewable energy generation to achieve the best results.
3. Integration and coordination: Intelligent control systems can integrate and coordinate energy storage systems with other energy systems, such as renewable energy power generation systems and grid demand response, to achieve multi-energy complementarity and optimization and improve the efficiency and reliability of the overall energy system.

## **4. THE ROLE OF ELECTRICAL ENGINEERING AND INTELLIGENT CONTROL IN ENHANCING ENERGY SUSTAINABILITY**

### **4.1 Improve the efficiency of renewable energy utilization**

Electrical engineering and intelligent control strategies play an important role in improving the efficiency of renewable energy utilization. The following is an analysis and introduction of these important roles:

First of all, the key technology network of renewable energy power generation systems designed by electrical engineering can improve the efficiency of energy conversion and transmission. Specifically, in wind power generation and photovoltaic power generation systems, there are design and optimization contents involving converters and inverters of power electronic equipment to achieve the purpose of efficient power conversion and grid connection. In addition, electrical engineering also involves the planning and design of power grids to ensure the safe and stable operation of renewable energy power generation systems and efficient energy transmission at the same time.

Secondly, the application of intelligent control strategies can improve the operating efficiency and reliability of renewable energy systems through real-time monitoring, data analysis and decision optimization. Intelligent control systems monitor and analyze the operating data of renewable energy power generation systems, identify and diagnose existing problems and faults, and take appropriate measures to solve them.

Finally, combined with the intelligent control strategy of electrical engineering, it is also possible to achieve multi-energy complementarity in renewable energy systems, thereby effectively improving the efficiency and reliability of energy systems. Specifically, on the basis of integrating renewable energy power generation and energy storage grids, the system's multi-energy complementarity and optimal configuration are carried out, and with the help of intelligent control strategies, energy storage and renewable energy power generation are effectively interactively coordinated, so as to achieve more precise dynamic adjustment and matching between energy supply and demand, and more effectively achieve full utilization and stable supply of energy.

#### **4.2 Promote safe and stable operation of energy systems**

Electrical engineering and intelligent control strategies play an important role in improving the safe and reliable operation of energy systems. The following is a discussion of this contribution:

First, electrical engineers design and optimize the power system according to the infrastructure and equipment of the energy system, so that the operation of the energy system can be carried out on a safe and stable basis. When designing, electrical engineers will fully consider the reliability and fault handling capabilities of the system to prevent the system from crashing due to hardware failure. In addition, electrical engineering also includes the protection and control equipment of the power system - circuit breakers and relay protection devices, which can quickly cut off the circuit in the event of a fault to prevent the further expansion of the accident from threatening the safety of equipment and personnel.

Secondly, the intelligent control strategy conducts real-time evaluation and prediction of the operating status of the energy system and timely discovers potential safety hazards. The intelligent control system analyzes key parameters in the system, uses advanced algorithms for prediction and early warning, and helps operation and maintenance personnel take timely measures to prevent accidents.

Finally, combined with the intelligent control strategy of electrical engineering, the automation and intelligence of the energy system can be realized, and the system operation efficiency and response speed can be improved. Through the automated control system, the energy system can be remotely monitored and controlled, reducing the risk of human intervention and operation, and improving the reliability and stability of the system operation. At the same time, the system operation parameters can be automatically adjusted according to real-time data and prediction results, so that the system can adapt to changes in the external environment and load demand.

#### **4.3 Reduce the environmental impact of energy systems**

Electrical engineering and intelligent control strategies play an important role in reducing the impact and pollution of energy systems on the environment, as shown below:

First, electrical engineers promote the adoption of clean energy in the design and optimization of renewable energy power generation systems to reduce dependence on fossil fuels. When designing the system, these electrical engineers will focus on the efficiency of renewable energy generation and its environmental impact. Renewable energy generation such as wind power generation and photovoltaic power generation will not produce greenhouse

gas emissions and other pollutants related to environmental pollution.

Secondly, the application of intelligent control strategies in energy systems can optimize the operating parameters and strategies of energy systems through real-time monitoring and data analysis. This can achieve energy conservation while improving energy utilization and reducing energy waste. Intelligent control systems can effectively analyze, process and diagnose the operating data of energy systems, identify and eliminate problems and faults in a timely manner, and thus optimize the operation adjustment and scheduling management between energy supply and consumption.

Finally, the integration and coordination of energy systems can be improved by combining intelligent control strategies for electrical engineering. Based on the multi-energy complementarity and optimization of energy systems, the efficiency and reliability of the overall energy system can be improved while achieving the goal of promoting efficient energy utilization and environmental protection. That is, multi-energy complementarity and optimization can be achieved through the integration of different energy systems, thereby improving energy efficiency and reducing environmental pollution.

## 5. CONCLUSION AND OUTLOOK

### 5.1 Summary of research conclusions

This paper discusses the role and significance of electrical engineering and intelligent control strategies in the integration of renewable energy, and draws the following main research conclusions and findings:

1. Electrical engineering and intelligent control strategies play an important role in the integration of renewable energy. Electrical engineering improves the efficiency of energy conversion and transmission by designing and optimizing renewable energy power generation systems, grid access technologies and power electronics technologies. Intelligent control strategies improve the operating efficiency and reliability of renewable energy systems through real-time monitoring, data analysis and decision optimization.
2. The application of electrical engineering and intelligent control strategies helps to improve the efficiency of renewable energy utilization. By optimizing power generation scheduling, load management and multi-energy complementation strategies, the maximum energy utilization efficiency and economic benefits can be achieved.
3. The application of electrical engineering and intelligent control strategies has contributed to the safe and stable operation of the energy system. Through the design and optimization of power system infrastructure and equipment, real-time monitoring and data analysis, automation and intelligent control strategies, the stability and safety of energy supply are ensured, thereby improving the operating efficiency and reliability of the energy system.
4. The application of electrical engineering and intelligent control strategies can help reduce the impact and pollution of energy systems on the environment. Through the design and optimization of renewable energy power generation systems, real-time monitoring and data analysis, integration and coordination strategies, energy efficiency can be improved, energy waste can be reduced, and environmental pollution can be reduced.

With the advancement and innovation of technology, the application of electrical engineering and intelligent control strategies in the integration of renewable energy will become more extensive and in-depth, thus playing a greater role in enhancing the sustainability of energy systems, promoting energy efficiency, and reducing environmental pollution. However, it also faces challenges such as system integration and the improvement of the scale and intelligence level of collaborative costs. Therefore, further research and innovation are needed to promote the application of electrical engineering and intelligent control strategies in the integration of renewable energy. From this point of view, in order to fully tap the potential of renewable energy and electrical engineering in energy systems and environmental protection, it is also necessary to strengthen the guidance and support of policies and systems on technology, application, and sustainable development while innovating technology.

### 5.2 Future Development Direction

electrical engineering and intelligent control strategies in renewable energy integration mainly include the following aspects:

First, with the continuous development of renewable energy technology, the system integration and collaborative work of electrical engineering and intelligent control strategies are facing increasingly severe challenges, which requires electrical engineers and developers of intelligent control systems to have interdisciplinary knowledge and skills so that they can effectively integrate different energy systems, form multi-energy complementarity and optimization, and thus improve energy utilization efficiency.

Secondly, in the integration of renewable energy, one of the important challenges faced by electrical engineering and intelligent control strategies is the cost and scale issue. With the continuous expansion of the scale of renewable energy systems, in order to reduce costs and achieve improved production efficiency and large-scale production, it is necessary to conduct in-depth research and improvement on related technologies.

Finally, intelligent control strategies and electrical engineering are the inevitable trend of renewable energy integration. The use of advanced sensor technology combined with big data analysis and artificial intelligence can further enhance the intelligence level of energy systems, thereby achieving a more efficient, reliable and intelligent state in energy management. In the integration of energy systems, the use of intelligent technology will optimize the use and management of energy.

In summary, there are three main challenges and development directions for the research of electrical engineering and intelligent control strategies in the integration of renewable energy in the future. First, explore the system integration and coordination; second, improve the cost and scale; third, explore and try to improve the level of intelligence. With the continuous advancement and innovation of technology, these will play a greater role in promoting the integration of renewable energy, thus playing an important role in the process of energy transformation and sustainable development. At the same time, we also hope that there will be more scientific and technological innovation and exploration in the future.