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# Research on the Combination of Wind Power, Photovoltaic Power Generation and Hydropower Generation

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**Abstract:**

In the practical work of combined complementary power generation, it is necessary to combine technical measures of wind power, photovoltaic power generation, and hydropower generation. In recent years, renewable clean green power generation energy has been widely promoted and applied, thus achieving the goals of saving traditional power generation energy and promoting the comprehensive benefits of power generation production. This article explores the basic implementation points of the power generation mode that combines wind power, photovoltaic power generation, and hydropower generation, and explores the path of technological improvement based on the current power generation production needs.

**Keywords:**

Wind power
Photovoltaic power generation
Hydropower generation
Key technical points of combination

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## 1. Introduction

Wind energy, solar energy, and hydropower are all renewable and clean energy sources for power generation. Only by optimizing the allocation and utilization of these existing clean energy sources, can power generation enterprises effectively prevent natural ecological damage during the power generation process and significantly improve their power generation capacity [1]. The new technological model combining wind, solar, and hydropower has been increasingly valued. Power generation enterprises should strive to build a complementary and recyclable energy power generation structure system, employing active technological improvement ideas to promote efficient allocation and utilization of renewable green and clean energy sources for power generation.

## 2. Necessity of combining wind power, photovoltaic power, and hydropower

### 2.1. Building a complementary power generation system

The construction of a complementary green energy power generation system with complementary advantages is currently demonstrating significant significance. This is primarily due to the increasing depletion of traditional energy sources for power generation. Wind, solar, and hydropower have renewable and environmentally friendly advantages. At this stage, if these three green and clean energy sources can be combined to achieve the goal of electric energy conversion, it will be beneficial to achieve the optimal complementary power generation effect of the clean energy power generation system, thereby effectively controlling the consumption of traditional energy sources for power generation. The complementary energy power generation system is currently being widely promoted and applied, objectively demonstrating the good complementary benefits of multiple clean energy sources for power generation [2].

### 2.2. Increasing the proportion of renewable energy in power generation

Compared with traditional coal-fired power generation energy sources, three complementary power generation energy sources wind, water, and solar energy all have the advantages of being clean, environmentally friendly, and recyclable. At this stage, traditional energy sources for power generation have been unable to fully meet the basic supply demand for power generation energy, which has led to the decision that renewable new energy sources for power generation need to be put into use to a greater extent. Combining various types of clean and recyclable energy sources for power generation should promote innovation in existing power generation technology models significantly, transforming the original high-energy consumption and high-pollution power generation operation implementation plans. Thus, it can be seen that promoting the proportion of renewable clean and environmentally friendly energy sources in power generation cannot be achieved without the combined use of the above three power generation energy sources as necessary support.

The key focus of increasing the proportion of renewable clean energy in the power generation process should be on strengthening macro-control practices. The internal structure of the industry will have a significant impact on the sound development process of the industry. The existing industrial structure of clean power generation cannot achieve the best level of reasonableness will result in a lack of long-term sustainable development momentum for the new energy economy [3]. Currently, under the operational conditions of the new energy power generation market, the focus on optimizing the internal structure of the economy should be reflected in improving the operational guarantee regulations for new energy power generation, employing standardized and refined management models to support the stable operation of the market. The concept of a low-carbon economy should rely on a sound industrial structure, and government regulatory authorities should provide macro-level guidance to enterprises within the market. Existing basic macro-control regulations should be promptly optimized comprehensively. Professional means of regulatory constraints should be employed to guide new energy power generation enterprises, ensuring diversified policy guidance and fiscal and tax support for these enterprises.

## 3. Engineering example of combining wind power, photovoltaic power generation, and hydropower generation

A large-scale renewable energy power generation system located in the Yellow River basin integrates photovoltaic power generation, wind power generation, and hydropower generation modes. Combining these three key clean and green power generation modes maximizes the advantages of complementary energy generation. The designers of the power generation project have focused on conducting in-depth technical research on the complementary power generation modes of these three clean and green energy sources [4,5]. They have built a stable, high-quality, and safe complementary clean energy power generation network system, which has facilitated the achievement of comprehensive operational efficiency indicators for the power generation project. As of now, the complementary power generation network structure system has been equipped with two large testing platforms and five experimental zones. It utilizes a reactive power coordination distribution network design approach to achieve optimal allocation of power generation system resources, significantly restoring the good natural ecological climate environment of the river basin.

Supported by a layered architectural structure, power generation enterprise personnel can accurately control and predict power generation errors across different periods. For the clean energy power generation mode of wind power integration, the key should be the rational design of the reactive power coordination distribution layer, the adaptive system adjustment layer, and the tracking control layer. When predicting the voltage regulation limit values, technical personnel should comprehensively consider the existing grid's active power and reference voltage parameters. They should accurately plot the fluctuation trajectory of the grid-connected voltage within one-minute intervals. Then, combined with the voltage regulation capability of the unit system itself, they should draw a real-time voltage output curve, thereby achieving the goal of adaptive grid voltage regulation and control.

**Figure 1** shows the voltage layered control design scheme in the wind power grid-connected mode. In this scheme, the voltage prediction control network structure system should include three different layers, which mainly consist of the adaptive grid-connected regulation layer, the reactive power coordination distribution layer, and the real-time tracking and control layer. The system designers set the interval frequency for monitoring grid-connected voltage to one minute and accurately implement adaptive grid voltage regulation based on the currently monitored active power prediction data signals. The wind turbine equipment system performs real-time optimization and adjustment of the operating power of the basic equipment, and the constant voltage tracking control mode is mainly designed as the MPC mode. On this basis, the various system components of the grid-connected voltage control can achieve close coordination and connection, effectively ensuring the scientific optimization and allocation of clean and environmentally friendly power generation energy in wind farms.

## 4. Key points of the design scheme combining wind power, photovoltaic power generation, and hydropower generation

### 4.1. Complementary wind-solar-hydro power generation system

The clean energy power generation system of wind, solar, and hydropower exhibits excellent complementarity. This complementarity is primarily reflected in the optimal complementary effect achieved by the three types of renewable and recyclable power generation

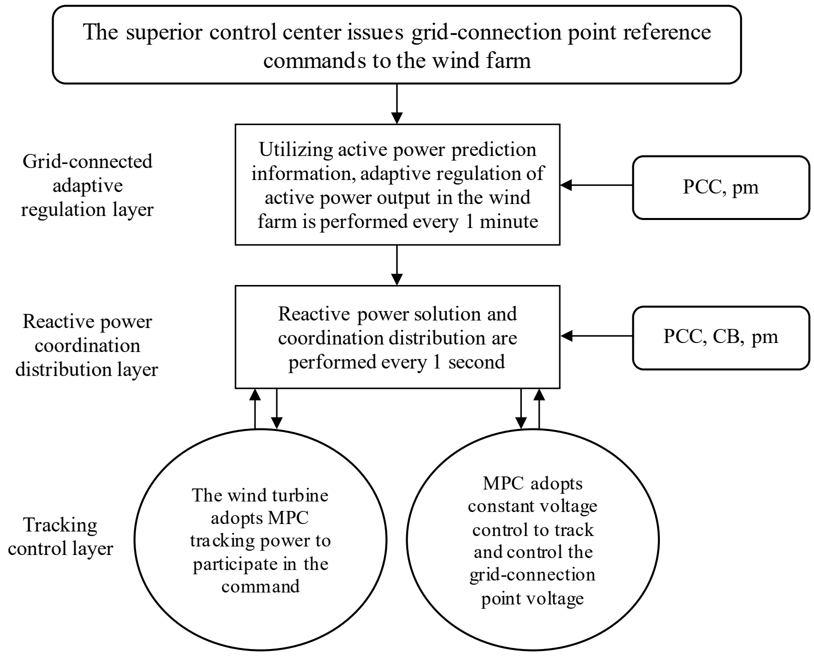


**Figure 1.** Layered voltage prediction control design scheme for wind power grid integration

energy sources. In the current era of information technology development, big data network technology has been integrated into smart photovoltaic power generation, significantly improving the operational data and information of the complementary combined power generation network. Domestically, the coverage of existing photovoltaic industrial parks is expanding, innovating the implementation mode of single-type energy power generation. For example, in Gansu province, efforts are being made to promote the construction of photovoltaic industrial parks, continuously expanding the large-scale power generation industry base for new energy. This has achieved an overall practical effect of expanding new energy power generation scale to tens of millions of kilowatts.

### 4.2. Flexible adjustment of backup power generation energy

Backup power generation energy constitutes an essential component of the complementary combined power generation system. Given the large-scale power generation network structure combining three clean and recyclable energy sources, it is difficult to avoid sudden network operation failures. The sudden failure and shutdown of the power generation system have pushed forward the implementation of backup power access operations in a short time to maintain the normal operation of the new energy power generation network [6]. Specifically, in sudden failures in wind turbine generators, hydropower generators, or photovoltaic grid-connected systems, other backup generators can be put into operation, effectively coordinating various types of clean energy power generation modes and preventing long-term interruption of power generation.

### 4.3. Comprehensive analysis of system operation characteristic indicators

The data indicators of system operation characteristics need to be accurately evaluated. By implementing a comprehensive and integrated analysis approach, the expected maximization of overall benefits for the power generation system can be effectively ensured. Therefore, technical personnel should accurately set the various operational characteristic data indicators for the power generation network system, ensuring precise evaluation of system power errors. Based on the scientific prediction of the operation accuracy of the power generation system, a cumulative probability curve can be obtained through statistics, improving and perfecting various existing evaluation data indicators. Additionally, for the currently designed complementary power generation network system combining multiple clean energy sources, it is necessary to accurately calculate the network output power for each time, providing scientific decision support under the clean energy power generation mode.

For example, **Figure 2** illustrates the structural model of an automated prediction algorithm for photovoltaic power generation grid integration. Based on constructing a prediction control model, technical personnel should make reasonable and scientific selections of model control objects. The differences between the prediction and actual models should be strictly controlled to ensure that the output indicators can be optimized in a rolling manner. In the process of model revision, adjustments should be made based on the actual output value errors for different periods, ensuring that the model control variables reach optimal standards through repeated model adjustments and corrections.

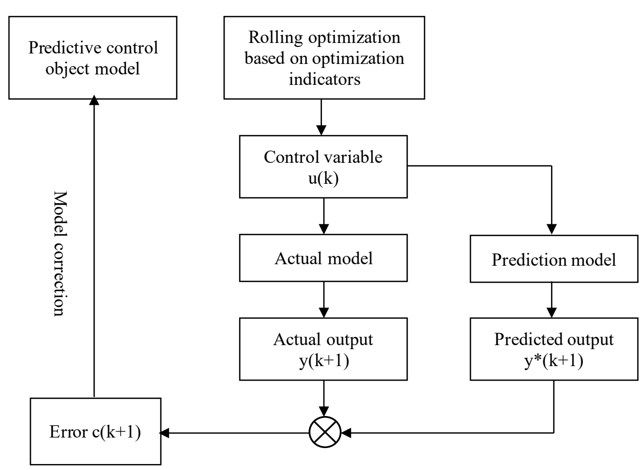


**Figure 2.** Prediction algorithm model for grid-connected photovoltaic power generation

## 5. Evaluation of technical indicators for the combination of wind power, photovoltaic power generation, and hydropower generation

### 5.1. Evaluation of system load matching

For a power generation system to achieve optimal operational efficiency, it must reach a good level of load matching. In current practical work, it is necessary to evaluate the load-matching degree of the power generation system across different periods. Technical personnel should first conduct an accurate evaluation based on the actual situation of system load matching and then make appropriate adjustments to existing evaluation indicators. The operating load of the power generation system should ensure optimal matching to prevent excessive consumption and waste of power generation energy due to system operating load errors.

### 5.2. System reliability evaluation

The goal of reliability evaluation should be to extend the service life of wind power systems by assessing multi-dimensional system reliability indicators to form objective analytical decision-making. The most critical practical improvement idea to achieve the system evaluation objective is to implement reasonable design indicators. System reliability should be reflected in every basic component of the power generation system, ensuring long-term safe and stable operation of the system's structural components. Under this premise, technical personnel should first conduct comprehensive system fault testing on the transmission system of the generator set until the existing fault locations of the transmission system can be accurately identified. Both internal structural faults and external friction damage faults of the transmission system should be promptly identified and addressed to prevent missing key fault areas in the transmission system structure. The important practical significance of the fault diagnosis model is to assist in achieving better fault diagnosis and processing efficiency, enabling comprehensive identification of early fault signs in the transmission structure of the unit [7].

For clean power generation systems combining three energy sources, system fault diagnosis and maintenance personnel should be skilled in combining the overall structural form of the transmission system to construct a three-dimensional and intuitive fault diagnosis model. Technical personnel should first accurately determine the system parameters and then build a transmission system model for fault diagnosis based on existing algorithms to achieve efficient system fault identification and diagnosis. The automated online monitoring device can accurately provide data information for system maintenance, helping to improve the safe operation efficiency of the entire unit. The system fault warning and online monitoring mode mainly rely on the system structure of the upper and lower computers, using the PC unit as a necessary automatic monitoring device.

### 5.3. System energy efficiency evaluation

The overall reliability of the power generation system is directly related to the operational efficiency of new energy power generation. Currently, energy-efficient indicator evaluations should be conducted for power generation systems combining various clean energy sources [8]. Power generation systems with complementary advantages can not only ensure a balanced configuration of existing network power generation energy but also rely on backup system power to maintain smooth and continuous power generation processes. Existing data indicators for evaluating and analyzing power generation energy efficiency need to be reasonably improved to ensure the scientific validity of evaluation conclusions.

## 6. Conclusion

After analysis, it is evident that the practical work plan combining wind power, photovoltaic power generation, and hydropower generation has significant feasibility. Therefore, it is currently worthy of comprehensive use in the field of power generation production practices. Engineering and technical personnel should conduct scientific optimization layout design for energy-complementary power generation system structures and flexibly adjust the total amount of backup clean power generation energy. Engineering and technical personnel need to use objective evaluation indicators to judge the load matching and operational reliability of the power generation system, highlighting the good overall benefits of clean energy power generation systems.

**Disclosure statement**

The authors declare no conflict of interest.

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