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Research on New Energy Grid-connected Control Technology in Electrical Engineering Automation for University Microgrids

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Abstract: This study aims to enhance grid reliability and operational efficiency by establishing an automated technology framework encompassing "data acquisition, control decision-making, and execution feedback". Through integrated digital modeling monitoring and information-based collaborative control strategies, the research utilizes edge computing, digital twin technology, and an optimized PSO-PID algorithm to demonstrate the automation system's effectiveness in optimizing grid status monitoring and process control. The findings validate the framework's capability to address renewable energy output fluctuations and load mismatch issues, providing technical support for large-scale renewable energy integration in university microgrids while addressing limitations of conventional control approaches.

Keywords: university microgrid, electrical engineering automation technology, new energy, grid-connected control

With the advancement of green campus construction in colleges and universities, the penetration rate of new energy sources such as photovoltaic and wind power in microgrids is gradually increasing. There is an urgent need for an automated technical solution suitable for the scenarios of colleges and universities to solve the problems of real-time monitoring and collaborative control during the grid connection process. This paper focuses on the application of electrical engineering automation technology in the grid connection of new energy in microgrids of colleges and universities. From the construction of the technical system, the optimization of control strategies to the verification of effects, it systematically explores the path to improve the stability of grid connection, laying a foundation for subsequent research and engineering practice.

1. Electrical Engineering Automation Technology in Microgrids of Colleges and universities

The automation technology system for the grid connection of new energy in microgrids of colleges and universities consists of three major modules: "data acquisition - control and decision-making - execution and feedback", and each module realizes closed-loop linkage through information links. The data acquisition module adopts a combined solution of "RFID+ intelligent sensors". Voltage/current sensors are deployed at the output end of the photovoltaic array, and smart electricity meters are installed on the load side. All data is preprocessed by the Huawei Atlas500 edge computing node and then transmitted to the microgrid control center through a 5G private network, with a delay controlled within 20ms. Avoid control bias caused by data transmission lag [1]. The control and decision-making module builds a digital twin model based on a cloud platform, and uses MATLAB/Simulink to construct a microgrid simulation model including photovoltaic, wind power, and energy storage. Through big data analysis, it predicts the output and load demand of new energy within the next 1 hour and outputs the optimal grid connection control strategy. The execution module, with intelligent circuit breakers and energy storage converters (PCS) at its core, adjusts the proportion of new energy output connection in real time according to control decision instructions.

2. New energy grid connection control strategies for electrical Engineering Automation Technology in Microgrids of colleges and universities

2.1 Pre-grid connection State Monitoring Strategy Based on Digital Modeling

State monitoring before the grid connection of new energy is a prerequisite for ensuring stability. Traditional manual monitoring relies on on-site inspections by operation and maintenance personnel, which has problems such as high missed detection rates and slow responses [2]. The digital monitoring strategy proposed in this paper realizes the three-level management of "real-time status mapping - abnormal early warning - pre-control" through the microgrid twin model. Edge nodes map the real-time parameters of new energy units (photovoltaic and wind power) to the twin model to build a dynamic visual interface. Based on historical data, an anomaly recognition model is trained. When the deviation of photovoltaic output voltage exceeds 1.5% or the fluctuation of wind power speed exceeds 5%, the system automatically triggers an early warning, with an early warning accuracy rate of over 92%. Output pre-control instructions for early warning status, for instance, when the wind power speed is abnormal, adjust the pitch Angle in advance to avoid frequency fluctuations after grid connection [3]. The core technical highlight of this strategy lies in multi-parameter correlation analysis rather than single-parameter threshold judgment. Traditional monitoring only focuses on the output voltage of photovoltaic power, while digital strategies simultaneously correlate two parameters: light intensity and component temperature. When the light intensity drops sharply by $100W/m^2$, even if the current voltage has not exceeded the threshold, the system will predict that the voltage will drop and start the energy storage discharge to recharge in advance, keeping the grid-connected voltage deviation within 0.8%.

2.2 Grid Connection Process Control Strategy Based on Information-based Collaboration

The core of the grid connection process is to solve the problem of "multi-source energy coordination and grid compatibility". This paper proposes to improve the PSO-PID control algorithm and optimize the voltage and frequency control parameters for the grid connection of new energy. The traditional PID algorithm has problems such as difficult parameter tuning and slow dynamic response. When the output of new energy fluctuates, the overshoot of voltage regulation can reach 5%. The improved algorithm optimizes the proportional coefficient (Kp), integral coefficient (Ki), and differential coefficient (Kd) of PID through the PSO algorithm, reducing the overshoot to 1.2%[4]. When the grid-connected voltage deviation is ΔU, the algorithm first searches for the optimal Kp, Ki, and Kd through PSO for 50 iterations with a convergence accuracy of 10^{-4}, and then outputs control signals through the PID controller to adjust the output voltage of the PCS, achieving rapid voltage stabilization. Relying on information-based collaboration, the "multi-source - load - grid" tripartite linkage is achieved. The control center receives grid dispatching instructions in real time and dynamically adjusts the grid connection ratio in combination with the prediction of new energy output and load demand [5]. During the off-peak period of the power grid, increase the proportion of wind power and photovoltaic power connected to the grid to 80% and reduce power purchases from the grid. During peak hours, if the output of new energy is insufficient, the energy storage discharge is initiated with a discharge power of 100kW to ensure the power supply to the load and reduce the cost of purchasing electricity during peak hours.

3. Verification of the new energy grid connection control results of electrical engineering automation technology in the microgrid of colleges and universities

3.1 Experimental Platform Construction and Parameter setting

To verify the effectiveness of the above control strategy, an experimental platform was built in the microgrid laboratory of a certain university. The platform parameters are shown in Table 1. The experimental period was 72 hours. Two modes, traditional manual control and the automatic control proposed in this paper, were adopted respectively to compare the grid-connected control effects. During the experiment, scenarios such as fluctuations in photovoltaic output (such as a sudden drop in midday light intensity from 1000W/m² to 600W/m²) and sudden load changes (such as a 50kW increase in load due to simultaneous startup of laboratory equipment) were simulated. Key indicators such as grid-connected voltage deviation, frequency fluctuation, and harmonic distortion rate were collected.

Table 1 Core equipment parameters of the experimental platform

Equipment type	Power rating	Output voltage	Control mode	Sampling frequency
Photovoltaic array	200kW	380V	MPPT(Disturbance observation method)	50Hz
Wind turbine	150kW	380V	Pitch change + doubly-fed speed regulation	50Hz
Energy Storage System	100kWh	380V	PCS Bidirectional conversion	50Hz
Edge compute node	-	220V	Data preprocessing + real-time transmission	50Hz
Smart Circuit Breaker	630A	380V	Electronic tripping + remote control	-

3.2 Control Effect Verification and Data Analysis

The experimental results are shown in Table 2. The automatic control mode significantly outperforms the traditional manual control in all indicators: In terms of voltage deviation, the average deviation of the automatic control is 0.8%, which is only 34.8% of that of the manual control, and the maximum deviation does not exceed 1.0%, meeting the national standard requirements. In terms of frequency fluctuation, the frequency fluctuation range of automated control is 49.9 to 50.1Hz, which is much smaller than that of manual control, ranging from 49.7 to 50.3Hz, ensuring the stability of the power grid frequency. In terms of harmonic distortion rate, the total harmonic distortion rate (THD) under automatic control is 1.2%, which is lower than 3.5% under manual control.

Table 2 Comparison of grid-connected performance of two control modes

Control indicators	Traditional manual control	Automatic control	Optimization range	National standard limit
Grid connection voltage deviation(%)	2.3±0.5	0.8±0.2	65.2%	±2%
Frequency	49.7-50.3	49.9-50.1	66.7%	49.5-50.5

fluctuation(Hz)				
Harmonic distortion rate(%)	3.5±0.4	1.2±0.1	65.7%	≤5%
Grid connection response time(s)	10.2±1.3	0.3±0.1	97.1%	-

Conclusion

The analysis demonstrates that the digital modeling monitoring strategy effectively addresses the high missed detection rate and slow response of traditional manual inspections. Through multi-parameter correlation analysis, grid connection risks can be predicted in advance. The enhanced PSO-PID algorithm combined with tri-party collaborative control strategy significantly improves voltage and frequency regulation performance, effectively compensating for the limitations of conventional PID algorithms. This automated solution adapts to the load characteristics and renewable energy profiles of university microgrids, enhancing grid stability and providing a practical technical pathway for efficient renewable energy utilization on campus.

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