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Power Flow Control Strategy of Wind Power Hybrid Power Grid Based on Digital Simulation Cloud Platform Architecture

Ke Zhou[1], Weichen Yang[2], Hao Bai[2], Tong Liu[2], Min Xu[2], Ruotian Yao[2], and Lifang Wu[1*]

[1] Electric Power Research Institute of Guangxi Power Grid Co., Ltd.
Nanning, Guangxi (China)
E-mail: **wu_lf.sy@gx.csg.cn**

[2] Electric Power Research Institute, CSG
Guangzhou, Guangdong (China)

Abstract. Wind power hybrid is a comprehensive utilization method of new energy, which can greatly reduce energy pollution, but there is also the problem of tidal flow difference, so the power flow regulation of wind power energy is to be solved at present. In this paper, the digital simulation platform is used to comprehensively judge the grid-connected demand, collect data such as wind speed, power generation and energy storage, and regulate the power flow of the wind power hybrid grid in combination with the problem of wind speed randomness. Secondly, the intelligent control function is used to judge the wind turbine transmission power hybrid grid and the power flow of the distributed power grid to balance the stability of the overall power flow, voltage and current of the wind power hybrid power grid. The results show that the digital simulation cloud platform collects the power flow data of the wind power hybrid power grid, generates abnormal power flow points, and supplements the power flow through alternative methods, and its regulation and control effectiveness is greater than 90%, and the amplitude of maintaining the power flow is between 10~20%. The wind power grid's grid-connected power flow regulation time is within 10s, and there is no damage to the wind turbine and energy storage battery. Therefore, the digital simulation cloud platform can realize the power flow control of the wind power hybrid power grid, maintain its overall stability, and meet the needs of new energy grid expansion.

Key words. Digital Simulation, Cloud Platform Architecture, Wind Power Hybrid Grid, Power Flow Regulation.

1. Introduction

Wind power hybrid power grid is a comprehensive development trend of new energy, which is mainly conducive to using the advantages hybrid to reduce the energy consumption, improve the operation sustainability of power grids, and achieve carbon neutrality in power grid development. However, problems such as frequent grid connections, abnormal power flow and large voltage changes in wind power hybrid power grids seriously affect the stability is the large power grids of 110 kV and 330 kV. Finding the power flow control means of wind power hybrid power grid is the main direction of the development of new power grids. The application of a digital grid to wind power hybrid programs can achieve rapid power flow regulation and identify abnormal voltage changes and abnormal current points [1]. However, the digital simulation platform itself has a weak storage capacity. It cannot better identify and record the information of the wind power hybrid grid, so some scholars suggest that the cloud platform should be applied to the wind power hybrid and prove that it has theoretical feasibility through theoretical analysis. Still, the digital simulation platform belongs to the comprehensive power grid. Through the regulation and control of the wind power hybrid power grid, which has problems such as delay and information processing, and some scholars believe that the power flow regulation is a comprehensive means [2], [3]. It has advantages in small grid connections, and the application range in large power grids, especially topological power grids, is relatively small, and it is necessary to judge with the help of intelligent methods and functions. The digital simulation cloud platform uses the cloud platform to collect wind turbine power generation information, form a wind power hybrid database, and record the power flow distribution of wind turbines [4]. In addition, the digital simulation cloud platform has the characteristics of low carbon and environmental protection, and it can realize massive amounts of data. Therefore, the use of a digital simulation platform for wind power hybrid regulation has high rationality at the theoretical level, and this paper integrates the bee colony algorithm to identify anomalies on this basis, aiming to shorten the time of power flow regulation and improve the accuracy of judgment of abnormal indicators such as voltage and current [5], [6]. In this paper, we first collect the geographical location and climate factors of the wind power hybrid grid, and record the wind speed and power of different wind turbines to form a comprehensive database. Then, the digital simulation cloud platform is used to monitor and identify the power flow of the power grid. The bee colony algorithm identifies abnormal wind turbine points, and early warnings are put forward to assist the digital simulation platform in making adjustments. Finally, the implementation results of the digital simulation cloud platform + bee colony algorithm are verified, and the verification indicators include the stability control of power flow and voltage, the accuracy of abnormal fan identification, and the time of regulation and feedback. Combined with the above analysis of the wind power hybrid power grid, the specific implementation fluid diagram is obtained (Figure 1).

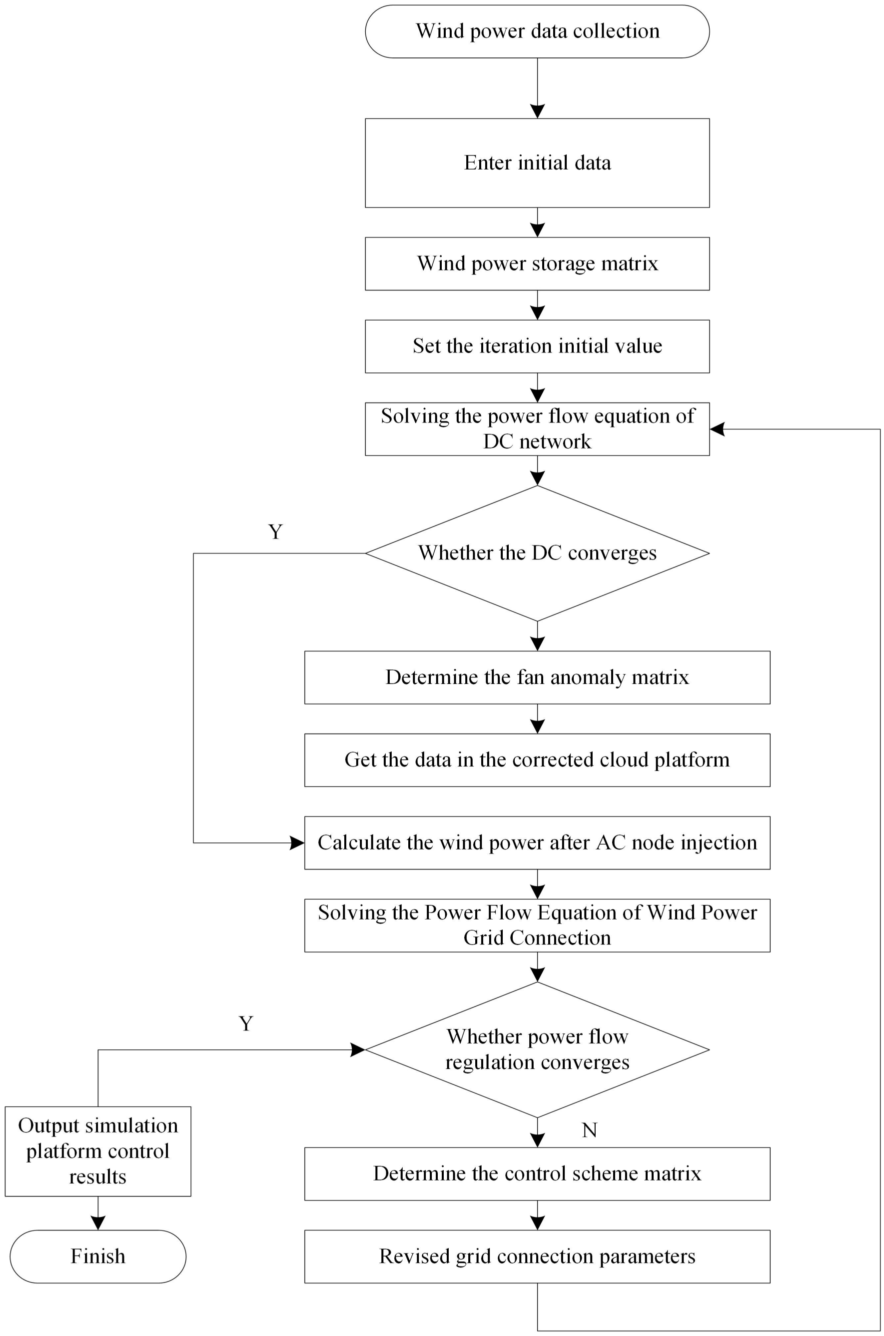

Figure 1. Power Flow Calculation Process of Wind Power Hybrid Grid

In order to optimal analysis of the overall cloud platform, redundant elimination function and other methods to analyze the abnormal power identification of the wind power hybrid grid. Due to the fast and strong convergence of the power flow of wind turbines, but few parameters, this paper uses iterative analysis to solve the power flow.

2. Literature Review

The detailed process of wind power mixing is represented as:

A. Power Flow Constraints for Wind Power Mixing

It has conducted empirical studies on the power flow regulation of wind power hybrid power grids [7], [8], and conducted case studies and found that the power flow regulation has a large randomness, which needs to be monitored, otherwise it is difficult to deal with it effectively. Specifically, the weather, wind speed, temperature and other random factors of power grid can be used as auxiliary variables[9],[10], and there is a correlation with the power of the generator and transformer, and then a single performance index is set u_i , in addition, the hybrid power grid needs to meet the constraints of stable operation x_i . Then the construction of the randomness function is shown in equation (1):

$$re = \min F\left(x_i, u_i\right) \quad (1)$$

In equation (1), the re stochastic variable representing single performance indicator covers all aspects of wind power blending, so data is collected as follows.

$$u_i = N_g \cdot \overline{P_{G1} \cdots P_{Gi}, V_{G1} \cdots V_{Gi}}, \overline{T_1 \cdots T_i, C_1 \cdots C_i} \quad (2)$$

In equation (2), the $P_{G1} \cdots P_{Gi}, V_{G1} \cdots V_{Gi}$ wind turbine and thermal generator in the wind power hybrid grid are described, i is the IDs of the wind power hybrid grid, and $C_1 \cdots C_i$ are the reactive power compensation data , in which the $T_1 \cdots T_i$ combined information of continuous monitoring and random monitoring of the power grid is described.

B. Power Flow Loss in Wind Power Mixing

In order to accurately analyze the power flow distribution of wind power mixing, a power flow control method based on a network matrix was proposed for the discrete and nonlinear power generation of wind power generation and the multi-objective nature of power flow distribution. According to the modulation principle of power flow balance of the thermal and wind power grids, the voltage and current are detected. Then, the matrix is revised the power flow amplitude, and the eigenvalues are solved. Finally, the comprehensive results of wind power generation are given to verify the convergence of the intelligent algorithm on the power flow of the wind power hybrid grid c_i .Judging the results of the algorithm more accurately, the adjustment coefficient is proposed, and the wind energy conversion loss of the power flow is calculated as follows by the vertical and horizontal crossing of the matrix to obtain the lowest power flow change and power loss F_{1obj} .

$$F_{1obj} = \sum_{i=1}^{N_g} a_i + b_i + c_i \cdot P_{G_i}^2 \quad (3)$$

In equation (3), c_i represents the consumption coefficient and a_i represents the loss coefficient , b_i represents the ith generator under constraints. The loss of a wind power hybrid grid is expressed as:

$$F_{2obj} = \sum_{i=1}^{N_g} P_{G_i} - \sum_{i=1}^{N} P_{D_i} \quad (4)$$

In equation (4), N represents the total number in the mixed grid, and P_{D_i} represents the active power load. Equations (4) and (3) cover the power flow of a mixed wind power grid, but it is a temporary grid.

C. Conditional Constraints on Wind Power Mixing

the constraint analysis is carried out, mainly to carry out the power balance constraints of each node, which are as follows.

The power flow constraints of the wind turbine points are calculated as follows:

$$P_{G_i} - P_{D_i} = \sum_{j=1}^{N} \left|V_i\right| \cdot \left|V_j\right| \langle G_{ij} \cdot \tan\left(\delta_i - \delta_j\right) \quad (5)$$

The power flow constraints of wind turbines are temporary constraints, which are only constraints of the simulation platform in a short period of time, and require subsequent integral constraints, which are calculated as follows:

$$Q_{G_i} - Q_{D_i} = \sum_{j=1}^{N} \left|V_i\right| \cdot \left|V_j\right| \cdot G_{ij} \cdot \tan\left(\delta_i - \delta_j\right) \quad (6)$$

In equations (5) and (6), the reactive and active power of the node load in the mixed grid is described, the conductivity of the connection path between the nodes of the wind turbine is Q_{D_i} , the connection path between the nodes represents is L, the voltage $\left|V_i\right|$ of each node in the mixing is less than the voltage $\left|V_j\right|$ after grid connection, and the voltage amplitude change of the node is less than 10%.

The constraints for each phase in a wind hybrid grid are as follows.

The power flow constraints of wind turbines are calculated as follows:

$$P_{G_i}^{\min} \le P_{Gi} \le P_{G_i}^{\max}, i = 1, 2, \ldots, N_g \quad (7)$$

The time constraints for wind turbine grid connection are as follows:

$$T_i^{\min} \le T_i \le T_i^{\max}, i = 1, 2, \ldots, N_t \quad (8)$$

The power constraints of the work done by the wind turbine are as follows:

$$C_i^{\min} \le C_i \le C_i^{\max}, i = 1, 2, \ldots, N_c \quad (9)$$

The overall power flow distribution of wind turbines after grid connection is as follows:

$$Q_{G_i}^{\min} \le Q_{G_i} \le Q_{G_i}^{\max}, i = 1, 2, \ldots, N_g \quad (10)$$

In equations (7)–(10), $P_{G_i}^{\max}$ represents the upper and $P_{G_i}^{\min}$ represents the lower limits of the active power of the ith generator in the wind power hybrid grid; $Q_{G_i}^{\max}$ represents the upper and $Q_{G_i}^{\min}$ represents the lower limits of the reactive power of the ith generator in the wind power hybrid grid,. $T_i^{\max}$ represents the upper and $T_i^{\min}$ represents the lower limits of the transformer ratio of the ith transformer in the wind power hybrid grid; $C_i^{\max}$ represents the upper and $C_i^{\min}$ represents lower limits of the reactive power compensation device of the i_{th} wind turbine in the wind power hybrid power grid. At the same time, the wind turbine, The constraints for the safe operation of a wind hybrid grid are expressed as:

$$|V_i| \le |V_i|^{\max}, i = 1,2,\ldots N \tag{11}$$

$$S_{Li} \le S_{Li}^{\max}, i = 1,2,\ldots N_1 \tag{12}$$

In equations (11) and (12), $|V_i|^{\max}$ represents the upper and $|V_i|^{\min}$ represents the lower limits of the voltage amplitude of i_{th} wind power in the wind power hybrid grid, S_{Li} represents the grid-connected power in the i_{th} hybrid grid, and N_1 describes the total number of branches in the wind power hybrid grid, and the overall change is shown in Figure 2.

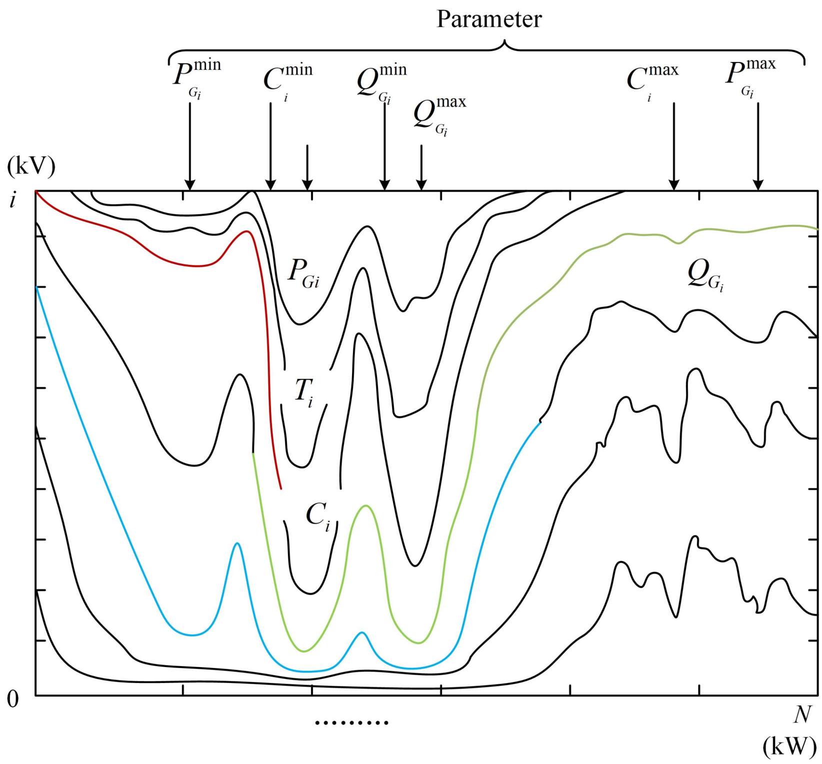

Figure 2. The Change Process of Wind Power Hybrid Power Flow after Grid Connection

D. The Influence of Digital Simulation Cloud Platform on the Power Flow of Wind Power Hybrid Power Grid

Set the weight coefficient ω and learning factor of the cloud platform c_1 , and its maximum power flow display c_2 speed $V_{\max}$ and maximum capacity of the platform are N . Then, the random value function was used to search for the position and the X_i power flow under the cloud platform V_i , and the initialization was carried out. The initialized adaptation value of each wind turbine is set to a minimum value, and P_i the minimum power flow of each wind turbine is compared to obtain the global power flow control scheme in the entire digital simulation platform P_g . Then, the adaptation values of each wind turbine in the wind power hybrid grid are obtained. If the fitness value P_i is better than the optimal value of the cloud platform, you need to update the optimal value of the cloud platform to the adaptive value, and if the fitness value is better than the optimal value of the wind turbine group, the overall optimal value is updated as P_g . The hybrid grid are updated by the following formula, which is calculated as follows.

$$\vec{V}_{ij}(t+1) = \omega \vec{V}_{ij}(t) + c_{ij} r_{ij} \left(p_{ij}(t) - \vec{x}_{ij}(t) \right) \tag{13}$$

In equation (13), the voltage amplitude of the i first j fan and the first c_{ij} power flow, the reactive power compensation device is p_{ij} the optimal value, and is calculated. If the speed of any wind turbine exceeds the maximum speed $V_{\max}$, the power flow of the wind turbine will be verified; If the position of any wind turbine exceeds the search boundary value, the position of the wind turbine will be locked as an outlier; All turbines have been tested for compliance with constraints, and the calculation can be stopped. If any of these conditions are completed, the calculation can be terminated and the optimal fitness value and the location of the optimal value of the wind hybrid grid can be output. If the termination condition is not met, an invalid solution is output. The power flow control of the wind power hybrid grid based on digital simulation cloud platform architecture is completed through the above process, and the specific theoretical model is as follows (Figure 3).

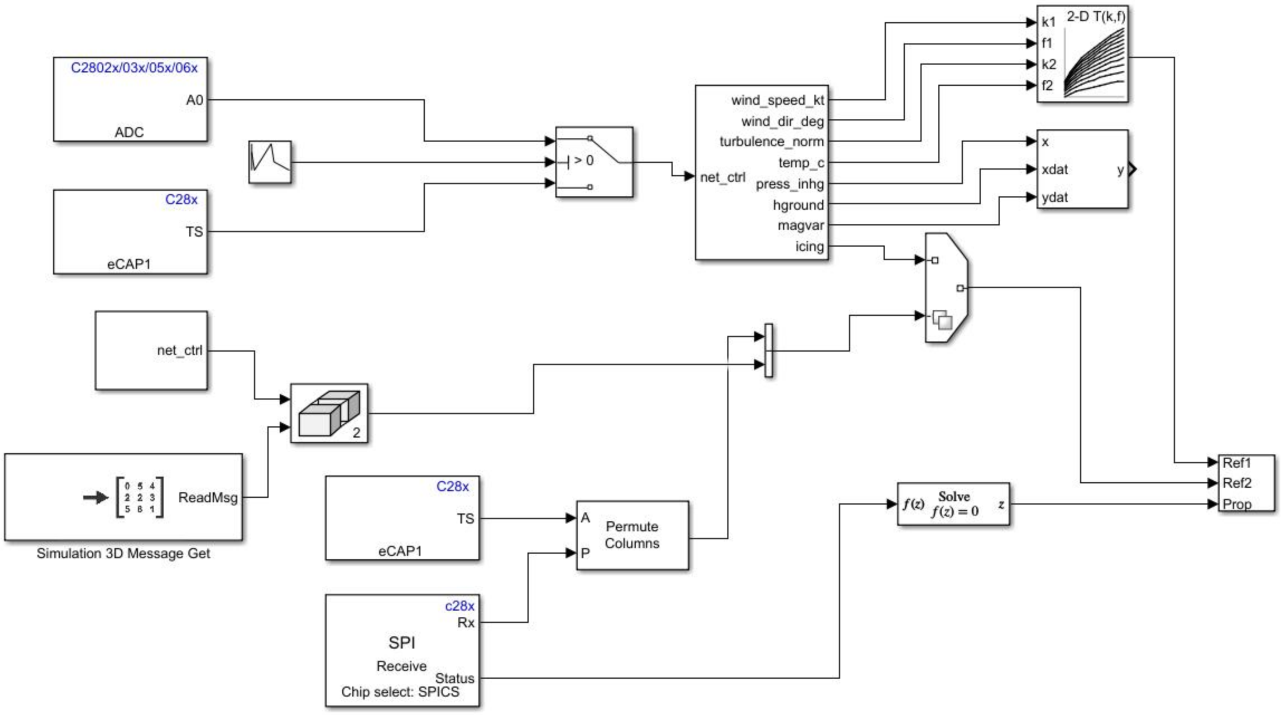

Figure 3. Theoretical Model of the Digital Simulation Cloud Platform Architecture

the power flow distribution of the wind power hybrid power grid, on the basis of the original double cross operator, the grid connection is carried out, and the central cross operator and the horizontal cross operator are alternately used through certain rules, and the data of the optimal cloud platform are analyzed in a selective and gradual way to achieve convergence speed control. In the simulation model, compared with other methods, iterative analysis has the characteristics of strong stability and high convergence efficiency, which can reduce the change loss of power flow. In the model, the control parameters of the voltage source converter are directly, and the control coefficient of the voltage source converter is introduced as the power flow control variable of the hybrid power grid, so as to make up for the shortcomings of the mixed power flow instability of different power fans. In addition, voltage and current can be used as solution variables and analyzed as indicative indicators under the constraints of power flow regulation. Based on the above power flow theory model, it can solve the frequent power flow change of wind power hybrid power grid, and provide theoretical support for the later simulation experiment verification.

3. Power Flow Control Analysis of Wind Power Hybrid Platform

A. *Case Introduction*

IEEE 14 was used as the simulated wind power flow control object to verify the connected, in which the voltage value of wind power is 10 kV, the impedance of the bus is 500 mH, the load resistance is 300 kΩ, the capacitor voltage is 400 V, and the DC capacitance of the grid-connected is 6.6 F. There are 12 wind turbines, including 6 in the south direction and 7 in the north direction, and the maximum output power of the wind turbine is 1200 kV. The main thermal power grid is 10 kV, and the grid-connected form is real-time grid-connected. Table 1 lists the parameters.

Table 1. Simulation Platform Parameters

Parameter	Value
Grid voltage/kV	10
Line reactance/mH	500
Load impedance/kΩ	300
Capacitor voltage/V	400
DC capacitance/μF	6000

Table 1 that the grid-connected form of wind power hybrid power grid is relatively common, and all its research results are representative to a certain extent.

B. *Power Flow Control Stability of Wind Power Hybrid Power Grid*

the convergence effect of wind turbines before and after the digital simulation platform is analyzed, as shown in Table 2.

Table 2. Comparison of the Convergence Results of Particle Swarm Optimization before and after Improvement

Number of stages	Iterations/Times	Changes in the power flow of the power grid	Regulation parameters
Before implementation	10	0.029	0.031
	50	0.030	0.031
After implementation	10	0.023	0.004
	50	0.023	0.004
Integrity	25	0.023	0.004

The analysis of the test results in Table 2 shows that before the improvement of the wind turbine cluster algorithm, when the number of iterations reaches 40 times, the fitness function gradually stabilizes, indicating that the wind turbine cluster algorithm has completed convergence at this time. After the optimization and improvement of the wind turbine cluster, when the number of iterations is 50 times, the fitness function gradually stabilizes, indicating that the improved wind turbine cluster calculation and generation have completed convergence at this time, indicating that the overall convergence speed of the improved wind turbine cluster algorithm is also high. The specific change process is shown in Figure 4.

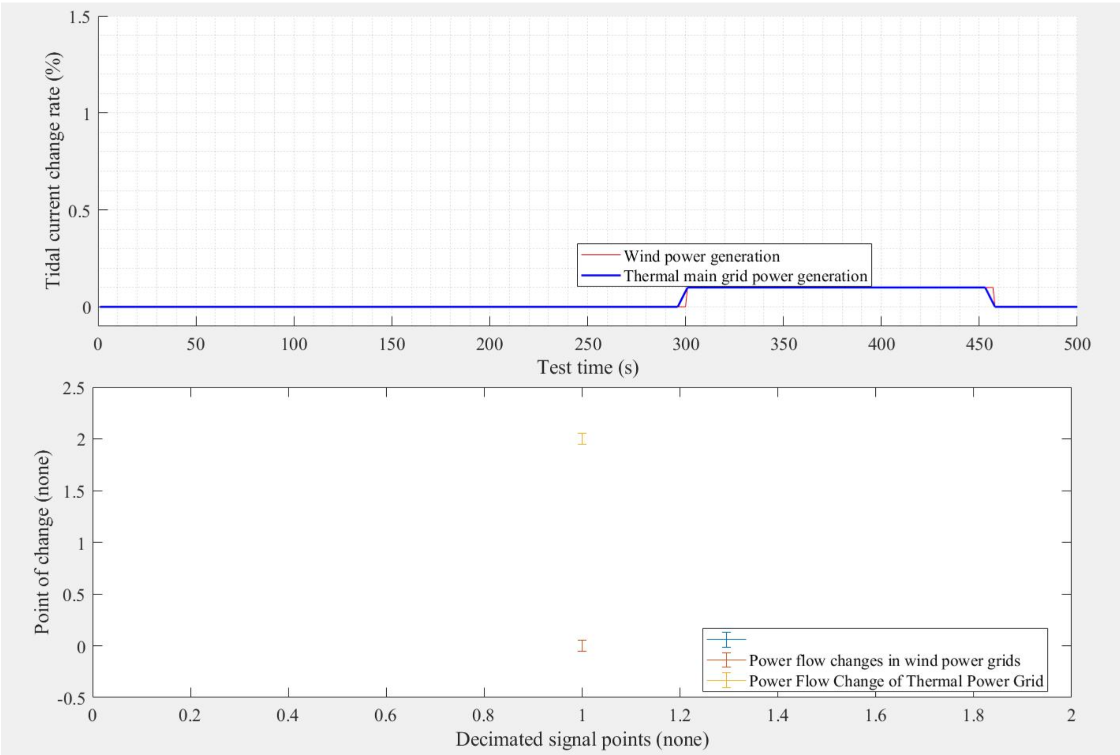

Figure 4. Stability Comparison of Wind Power Grid Hybrid Grid after Grid Connection

From the pathology of the power flow stability of the wind power hybrid power grid in Figure 4, it is found that the change range is relatively small. The power flow change of the network is relatively small. When performing test signal analysis, it will be found that there is no power flow change at other times. At the information test point numbered 1, there are signal changes in both, indicating that the response of the two changes is simultaneous. The wind power grid can be adjusted. There is no delay in the control time of the controller, which indirectly proves its control stability and control effect.

C. *Power Flow Regulation Time of Wind Power Hybrid Power Grid*

The power flow control time of the wind power hybrid power grid is an important indicator for the stability of the enterprise enrollment power grid and the later mediation plan test. The delay of control time and premature control time will actually cause errors in power flow control, and the power flow action cannot be accurately realized. Therefore, to control the entire power flow. Control time is analyzed and cloud mobilization and cloud data analysis in the digital bound cloud platform are measured. The test results are as follows.

Table 3. Power Flow Control Time

Test time	Wind power grid			Thermal main grid		
	Power flow	Voltage	Current	Power flow	Voltage	Current
8:00~16:00	0.97	1.41	1.06	0.393	0.747	0.902
16:00~22:00	0.94	1.32	1.01	0.360	0.706	0.88
1~2 onth	0.70	1.27	0.92	0.356	0.700	0.87
9~10 month	0.40	1.23	0.63	0.19	0.87	0.79
100~200/kΩ	0.23	1.02	0.52	0.12	0.65	0.52
Load rate 80~90%	0.95	1.04	0.46	0.22	0.72	0.44

According to the stability of power flow control, the control time is analyzed, and the stability of the control time and the delay rate are compared, the result as follows (Figure 5).

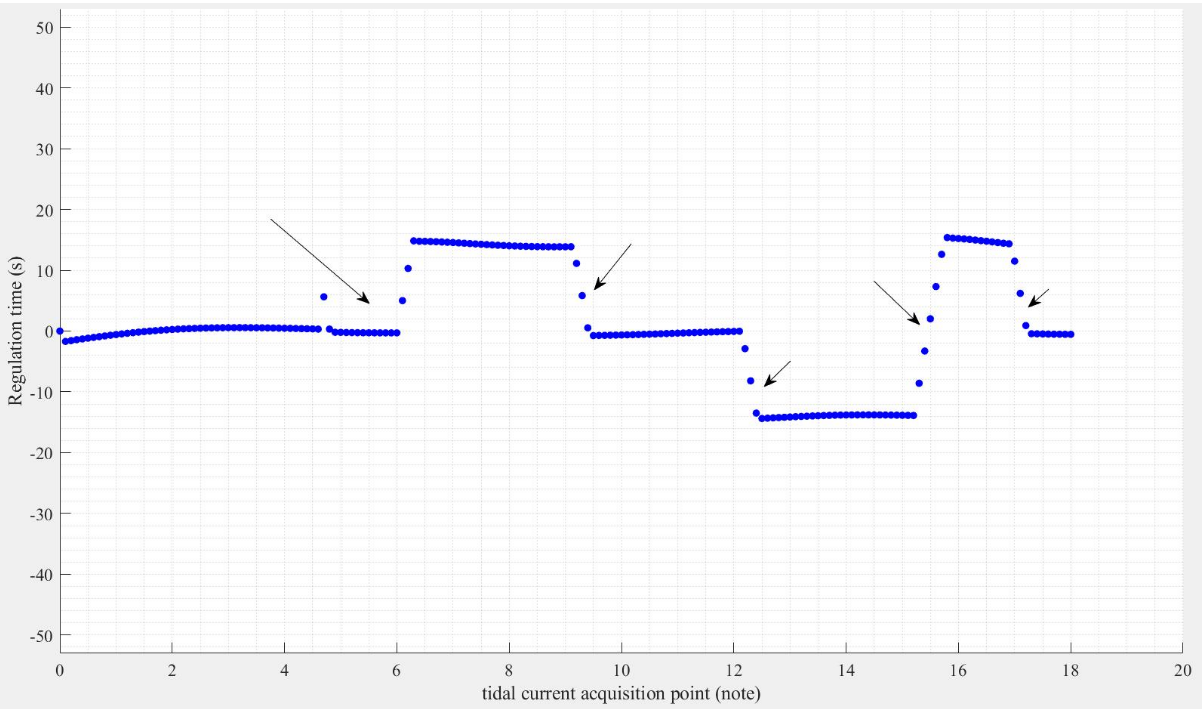

Figure 5. Response Time of Power Flow Test Point

It can be seen from Figure 5 that the power flow changes in stages, the response time is relatively stable, within 10s, and it fluctuates sinusoidally, the change process is stable, and there is no linear change, indicating that there is no delay. The test results show that under the constraints of voltage, current and power flow, the fine-tuned power flow log is consistent with the predicted value after iteration, and the digital simulation cloud platform can improve the operation efficiency in power flow control of wind power hybrid power grid. The power flow adjustment in different periods is as follows (Figure 6).

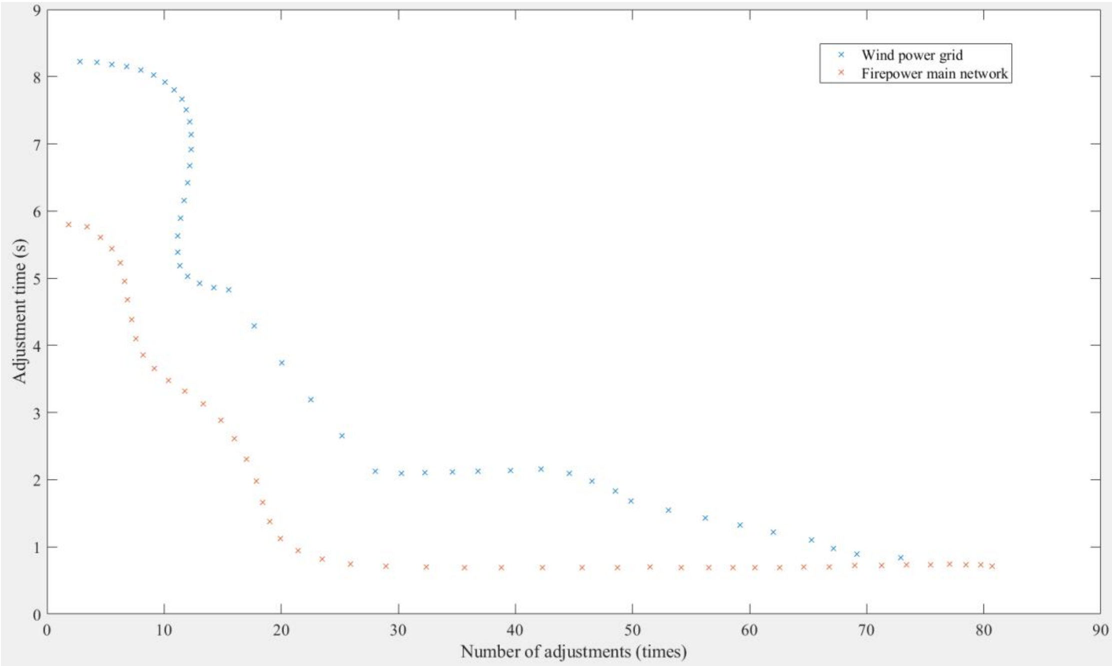

Figure 6. Adjustment Frequencies of Different Power Flows

It can be seen from Figure 6 that the accuracy of the proposed method for power flow control of wind power hybrid power grid is verified, and the digital simulation platform is used to analyze the fitting results between power flow control and actual power flow control of wind power hybrid power grid.

D. Distribution Characteristics of Power Flow Control in Wind Power Hybrid Grid

The digital simulation cloud platform has a very high probability density for power flow control of wind power hybrid power grids. The actual power flow control of wind power hybrid power grids is frequently adjusted and almost completely matches the actual situation. The results show that the power flow frequency of wind power hybrid power grid based on the digital simulation cloud platform architecture, it can more accurately complete the power flow control of wind power hybrid power grids, analyze the positions of different wind turbine points more intuitively, compare the vertical and horizontal crossing algorithms with the network matrix algorithm, and compare the convergence efficiency of power flow control in wind power hybrid power grids. The comparison results are shown in Figure 7.

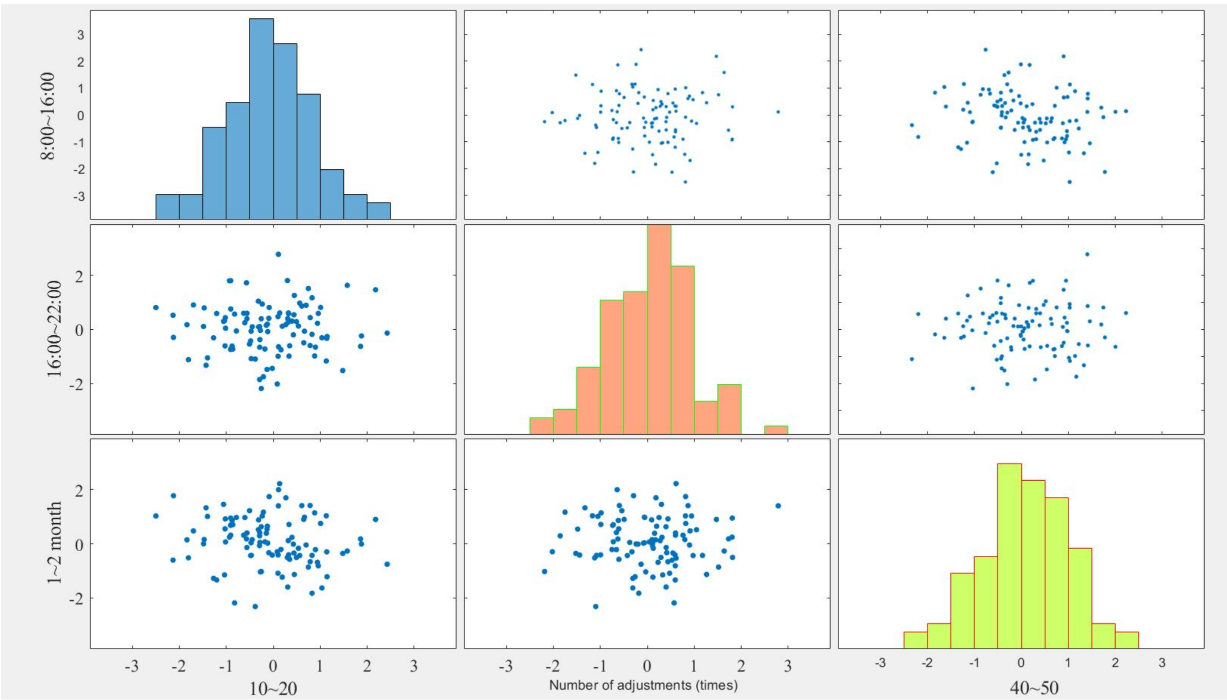

Figure 7. Comparison of Convergence Efficiency of Power Flow Regulation in Wind Power Hybrid Grids with Different Algorithms

The power flow adjustment results of the wind power hybrid power grid in Figure 7 show that the digital simulation cloud platform can complete the acquisition of all optimal solutions when the number of iterations is 20 times, and the convergence process has been relatively stable. However, the previous algorithm can complete the acquisition of all optimal solutions when the number of iterations is 40 times, and the voltage and current complete the acquisition of all optimal solutions, indicating that the digital simulation platform needs a small number of iterations to adjust the power grid power flow and the overall power flow. In hybrid power grid power generation, the regulation frequency of the main grid is lower than that of the wind power grid, so it can reduce power generation costs. The bee colony algorithm looks for wind turbines, improves the power flow control scheme of wind turbine clusters, and can promptly discover the power flow running status in the hybrid power grid, effectively adjusting the voltage and current of the wind power hybrid power grid, and maintain the stability of the power flow.

4. Conclusion

Wind power hybrid is the main trend of power grid development at present. the energy consumption and cost of thermal power generation in the network and improve the environmental protection of the whole power generation. It is in line with the national renewable energy operation policy. However, there are power flow regulation problems in the process of wind power hybrid, and high-quality power transmission cannot be carried out. Therefore, this paper makes an in-depth study on the power flow control strategy of wind power hybrid grid based on digital simulation cloud platform architecture. Firstly, the power flow problem in wind power hybrid power grid is expounded, and then the power flow control of wind power hybrid power grid based on digital simulation cloud platform architecture is completed by improved wind turbine cluster optimization to adjust the power flow of wind power hybrid power grid. The research results show that the data construction of the simulation platform can reduce the power flow regulation frequency of wind power hybrid and shorten its regulation time, so that its regulation accuracy is more than 90%, its stability is more than 85%, and the regulation time is controlled within 10 seconds.

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