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INTELLIGENT PLANNING OF TRANSMISSION NETWORKS: ADDRESSING UNCERTAINITIES THROUGH ARTIFICIAL INTELLIGENCE

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Abstract:

Power grid planning is a critical aspect of power grid topology, traditionally relying on manual methods that are prone to various uncertainties. These uncertainties, both subjective (stemming from human judgment) and objective (resulting from data limitations), can significantly affect the reliability and efficiency of the planning process. This paper introduces an artificial intelligence (AI) approach designed to enhance the intelligent planning of transmission networks. By utilizing AI, the proposed method systematically analyzes and optimizes the factors contributing to uncertainties in traditional planning methods. The AI-based model processes and evaluates topology data comprehensively, leading to more accurate and reliable planning outcomes. Furthermore, continuous monitoring is integrated into the system to ensure that the planning process remains dynamic and responsive to real-time changes. The final planning results are generated with a high degree of precision, effectively minimizing the uncertainties that plagued earlier methods. Consequently, AI-driven techniques not only meet the stringent requirements of intelligent transmission grid planning but also facilitate the continuous evolution and optimization of transmission network planning. This approach is well-suited to support the ongoing development and complexity of modern power grids, ensuring more resilient and efficient grid topology.

Key Words: artificial intelligence, smart grids, grid planning, uncertainty.

1. Introduction

The intelligent planning of the transmission grid is a comprehensive evaluation method of the power grid modeling topology, and the modeling topology data and power grid planning should be

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carried out the data is comprehensively evaluated, but the original manual planning method is prone to subjective and objective uncertainty [1]. At present, the original manual planning of transmission grid planning faces more uncertainties [2]. To apply artificial intelligence methods to transmission network planning and identify interference factors for better planning. However, the load forecasting and power planning analysis is still not ideal [3]. To this end, some scholars have proposed artificial intelligence methods to improve the intelligence of transmission networks by analyzing[4] the load forecasting and power planning of transmission grids [5] and conducting time series analysis on transmission network planning formulation rationality and certainty of planning.

2. Intelligent planning and analysis of transmission grid

Intelligent planning analysis of transmission networks makes reasonable planning for power grid planning and load forecasting [6] and detects the change characteristics of target data [7]. Intelligent planning of transmission grids [8]. The intelligent planning analysis of the transmission network is mainly based on the modeling algorithm and the peak of application [9]. The artificial intelligence method completes the comprehensive intelligent planning of the transmission network by assembling and analyzing the modelling topology data Analysis [10]. Where the direction of change in the peak of the target data represents the amplitude value [11]. There are four definitions of AI methods, which are as follows.

Definition 1: The arbitrary modelling topology data is x_{i}, the target data formulation function is J_{i}, the planning set is $p(y_i)$, and the time length is c_{i}. Well, the calculation process is shown in Equation (1).

$$p(y_i)=\frac{1}{2}\cdot\sqrt{a^2+b^2}\cdot J\times c_i\cdot x_i \quad (1)$$

Definition 2: The forecast plausibility function is $f(x)$, l is planning reasonableness, Yl is planning reasonableness and Yq is determinism. Well, the calculation process is shown in Equation (2).

$$f(x,P)=x\xrightarrow{y}\sqrt{Y_m\cup Y_b}\div\sqrt{b^2-4ac}\cdot x \quad (2)$$

Definition 3: Planning result function, planning change is $l(x_i)$, planning set is $\bar{x}_{\mathrm{i}}$, modeling number is col_{i}. The calculation process is shown in Equation (3). $h_i\ l(x_i)$

$$l(x_i)=\sum c_i\div h_i\cdot x_i\cdot\frac{dy}{dx}\cdot(a+c) \quad (3)$$

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Definition 4: The load forecast function is $f(x,b)$,the threshold of the plan is w,l is the planning error. Well, the calculation process is shown in Equation (4).

$$f(x)=\sum_{i=1} x_i \times w \div \tau_i \cdot \frac{1}{n} \cdot \mu_X \quad \square\square\square \quad \square\square\square\square\square\square\square\square\square\square\square\square$$

3 Artificial intelligence methods for planning

In the process of artificial intelligence transmission network planning, the grid topology information should be comprehensively calculated to reduce the uncertainty in the planning. According to the artificial intelligence theory, identify the constraints with differences, and calculate the rationality of planning formulation. Therefore, conducting a random analysis of the planning and related constraints of different electricity market conditions is necessary.

Definition 5: The target data function is $F(J_i)$, when a peak occurs, the planning variable is, and the constraint is calculated as shown in Equation (5).

$$F(x_i)=\frac{k(x_i^{\,2})\cdot(1-P_i)}{Ya\cdot\sqrt{1-k^2}}\cdot\frac{-b\pm\sqrt{b^2-4ac}}{2a} \quad \square\square\square\square\square\square\square\square\square\square\square$$

Formula: If $F(x_i)\geq A$the intelligent planning results are reasonable, otherwise the constraints that do not meet the requirements must be analyzed. If it $F(x_i)\lhd A$states that the smart planning results do not meet the constraints, readjust them.

Definition 6: The constraint determination function is $j(k)$, calculated as shown in Equation (6).

$$j(k)=\sqrt{2}\cdot y(x_i,y_i)\cdot e_i\cdot f(x_i)\cdot(y-x) \quad \square\square\square\square\square\square$$

Intelligent planning to reduce the occurrence of uncertainties requires sampling analysis of load forecasting and grid planning, including subjective and objective uncertainty. In addition, the planning scheme is analyzed according to the artificial intelligence method.

Step 1: The planning data of the AI method is collected, the binding nature of the intelligent planning is determined, and the intelligent planning is comprehensively evaluated, and then the planning is determined Conditions for judgment.

Step 2: Collective calculation of load forecasting and grid planning included in the transmission grid, and continuous analysis of multi-stage transmission network planning.

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Step 3: Ensemble the calculation for planning formulation, terminate the analysis if the constraints are exceeded, or the forecast data changes, otherwise, the set calculation is performed.

The AI method planning is analyzed based on the original AI method, and the specific parameters are shown in Table I.

TABLE I. PLANNING DATA STATUS OF ARTIFICIAL INTELLIGENCE METHODS (UNIT: %)

Parameter	Discreteness	Effectiveness
Grid size	93.51	89.76
Number of branches	92.64	92.22
Number of nodes	91.20	91.67
Number of loads	92.76	92.84

During the research in Table I, it is found that AI method can analyze network scale, network branches and network nodes, and there is a big difference between AI method and artificial intelligence analysis method. From this result, we can see that AI method can realize comprehensive data analysis and provide relevant support for later research. Relatively speaking, the data distribution state of AI intelligent analysis method is shown in Figure 1.

From the contents in Figure 1, it can be seen that the data of AI method is discrete, and mainly distributed between 82% and 86%, which shows that the data dispersion is scattered and meets the relevant analysis requirements. At the same time, there is no concentrated result in the overall distribution of data, which shows that the normality of data is good, the overall structure and data value are reasonable, which can lay the foundation for later analysis and will not affect the later calculation results.

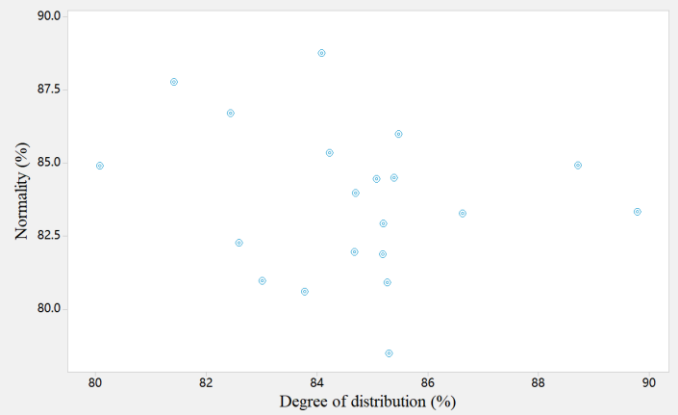

Figure 1: Data distribution status of artificial intelligence methods

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TABLE II. COMPARATIVE PLANNING OF ACCURACY AND RATIONALITY (UNIT: %)

Fangfa	Plan direction	parameter	Accuracy	Rationality	Average change
Artificial intelligence approach	First-level planning	randomness	92.66	92.64	0.15
		Ambiguity	94.21	91.20	2.09
		complexity	91.54	92.76	1.32
	Secondary planning	randomness	94.43	92.66	1.75
		Ambiguity	93.39	90.06	2.25
		complexity	93.51	94.05	0.76
Original manual method	First-level planning	randomness	89.48	89.16	1.36
		Ambiguity	80.04	81.48	1.53
		complexity	85.60	86.55	1.15
	Secondary planning	randomness	86.76	83.47	3.09
		Ambiguity	87.17	78.31	8.32
		complexity	81.77	83.69	2.75
Plan for comparison		X2=16. 121, P<0.06			
Parameter mining times = 56 times					
Parameter adjustment rate = 0.35					
Parameter compatibility = 0.89					

The planning of artificial intelligence methods should be kept complete, otherwise it will increase the randomness and ambiguity of planning, and the accuracy and rationality of the planning results of artificial intelligence methods will be detected and specifically planned This is shown in Table II.

From the data analysis in Table II, it can be seen that there is no significant difference between the analysis results of the early level and the late level of the artificial intelligence algorithm, and the randomness, complexity and change range have not changed greatly. The calculation accuracy, rationality and average change are at a high level, greater than 90%, which is significantly superior to the traditional artificial method. Although the accuracy and rationality of traditional artificial method is better than 80%, it is slightly inferior to artificial intelligence method. Therefore, the artificial intelligence method proposed in this paper is better. In addition, from the data in Table II, it can be seen that the accuracy and rationality of artificial intelligence methods are relatively stable,

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and the change range is small. This result shows that the artificial intelligence analysis method has strong data processing ability, can judge complex data, is not interfered by external data, and the calculation result is relatively stable. In order to better reflect the calculation results, it is necessary to analyze the above data continuously and observe the continuity of the calculation results. The specific calculation process is shown in Figure 2. It can be seen from Table II that the accuracy and rationality of artificial intelligence methods are greater than 9 1%, the mode change is less than 2, and the change amplitude of different methods is greater than 8. There are significant differences. At the same time, the randomness, ambiguity, and complexity changes are relatively small, so the overall planning of artificial intelligence methods is better. However, the rationality and accuracy of artificial methods vary greatly, traditional the accuracy and rationality of manual methods are less than 80%, which is relatively poor. In the market conditions, the rationality and accuracy of AI method planning change as shown in Figure 2.

It can be seen from Figure 2 that in the data sampling comparison, the rationality and accuracy of artificial intelligence method planning are more concentrated, while the traditional manual method is more concentrated the rationality and accuracy of the planning are poor, which is consistent with the results of the study in Table II. The reason is that the artificial intelligence method analyzes the rationality of the planning such as the formulation of transmission network planning, and calculates the convex function values of different values, which removes the uncertain factor values in transmission network planning to simplify its complexity.

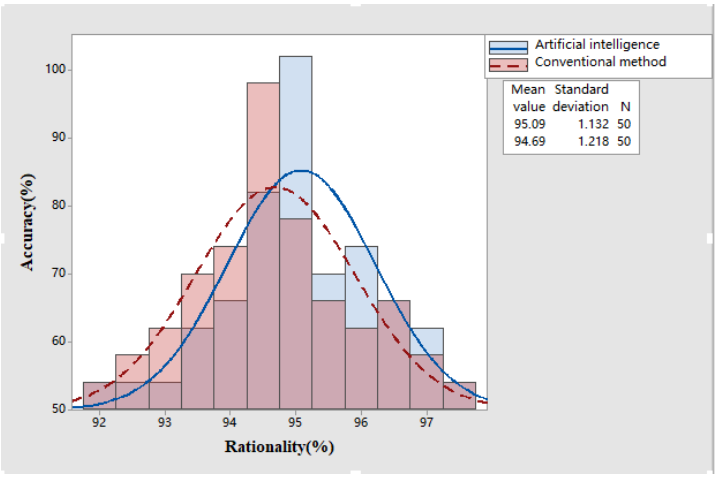

Figure 2 **Comparison of accuracy and rationality of planning of different algorithms**

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From the data analysis in Fig. 2, it can be seen that the rationality and accuracy of artificial intelligence algorithm are higher than those of traditional methods, and the peak curve is biased to the right, which further proves the effectiveness of the calculation results. In the area of peak curve, the area of artificial intelligence algorithm is larger, which shows that its results are more effective and the overall calculation results are better. The main reason for the above results is that artificial intelligence algorithm combined with big data, cloud computing and other aspects can comprehensively judge complex data, optimize the data results and eliminate redundant data in the middle.

The time of AI method planning is an essential indicator of planning efficiency, including subjective uncertainty, objective uncertainty, etc., and the specific planning is shown in Table III.

According to the data in Table III, the results of artificial intelligence method in time planning are relatively stable and take less time, which shows that the calculation time of intelligent planning method is relatively rational. Relatively speaking, the traditional manual calculation method takes a relatively long time, which shows that manual calculation method has certain disadvantages in data processing and redundant data elimination. Artificial intelligence algorithm uses big data, cloud computing and other methods to obtain more comprehensive data eigenvalues, better build network topology, and carry out multi-dimensional analysis of data, which can effectively eliminate abnormal values of data, reduce the complexity of data, and provide support for later simplified calculation. In order to better analyze the advantages of artificial intelligence algorithm, the relevant data are calculated in stages, and the specific calculation results are shown in Table III.

TABLE III. PLANNING TIME OF ARTIFICIAL INTELLIGENCE METHODS (UNIT: MINUTES).

Method	Time	Subjective uncertainty	Objective uncertainty	Data dispersion
Artificial	10~20	95.03	95.64	0.342
intelligence	20~30	93.18	92.57	
approach	30~40	93.15	91.68	
Traditional	60~70	82.19	84.89	
manual	70~80	84.74	89.57	
methods	80~90	86.86	84.76	
Difference of different methods = 0.56				
Method independence = 0.23				
Data Relation = 0.421				

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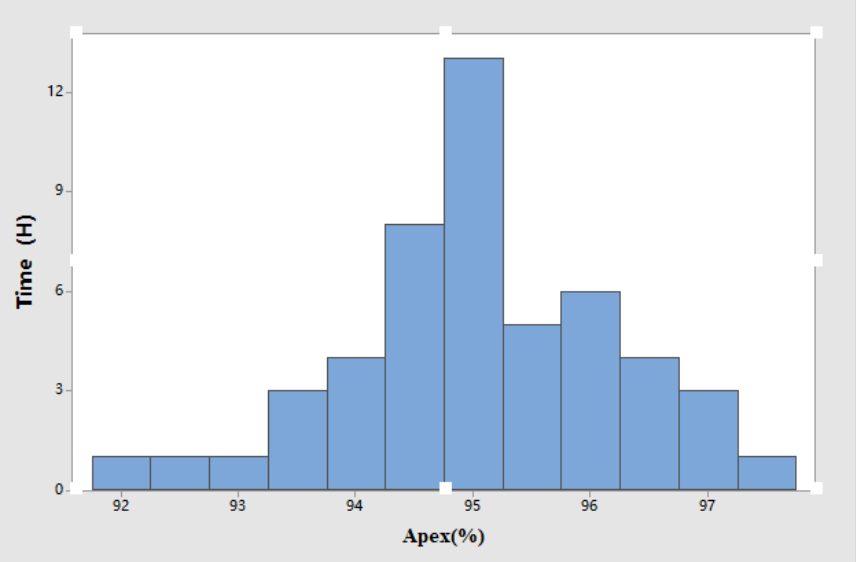

Figure 3. Comparison of planning data and time for different methods

From the data in Fig. 3, it can be seen that the calculation time of artificial intelligence algorithm is less than 12 seconds, and the calculation peak value is relatively concentrated, and it decreases from the peak value to both sides, which meets the requirements of normal distribution. In addition, the peak value of artificial intelligence algorithm is at 95%, which is significantly better than the traditional manual calculation method. In addition, in terms of peak distribution, the reduction range of the right side is smaller than that of the left side, which shows that the later calculation process is relatively stable, while the previous results are larger, mainly because of complex data analysis in the early stage to reduce the effectiveness of the analysis results. Through the analysis of Figure 3, the planning data value of artificial intelligence methods is higher, and the time is faster, while the planning of traditional manual methods. The comprehensiveness is poor, and the planning time is slow.

4. CONCLUSION

In the transmission grid planning process, the manual methods of the past cannot be effectively planned. Based on this, this paper proposes an artificial intelligence method to comprehensively evaluate the transmission network planning and determine the final plan. Reduce the complexity of the planning process by comprehensively calculating planning expectations through artificial intelligence methods. Intelligent planning is carried out with constraints, and the uncertainties in transmission network planning are studied to improve the rationality of planning. The results show that the comprehensiveness and rationality of artificial intelligence methods are greater than 90%.

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However, the rationality and comprehensiveness of traditional artificial methods are quite different, and the uncertainty factors are highly disturbed and relatively poor. At the same time, the planning time of artificial intelligence methods is relatively fast, and the range of changes is small. Among them, the value of uncertainties in the planning of artificial intelligence method is stable, the time is short, and the overall transmission network planning scheme is more ideal.

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