Accurate investment evaluation model of power grid based on Improved Fuzzy Neural Inference

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Abstract. In the accurate investment evaluation of power grid, the existing model does not consider the uncertainty of the actual evaluation object, and the evaluation subject mainly relies on subjective judgment, resulting in low information utilization rate. Therefore, the accurate investment evaluation model of power grid is designed based on Improved Fuzzy Neural Inference. The evaluation index system is established from three aspects of power supply capacity, power supply quality and power grid benefit of power grid investment, so as to achieve the purpose of giving consideration to both economic and social benefits. Based on the Improved Fuzzy Neural Inference, the membership function algorithm is designed, and the parameters are adjusted to obtain the best fuzzy inference results. According to the membership function and index improvement value, the standardized data table is established. The indicators of the same level are quantified, and the weight attributes are solved to complete the construction of accurate investment evaluation model of power grid. The experimental results show that the design model has certain advantages in the utilization rate of investment information, which is 10.59%, 15.40% and 9.95% higher than the existing models. It proves that the accurate investment evaluation model of power grid constructed in this paper is closer to the actual situation and has good application effect.

1. Introduction
With the steady recovery of China's economy, the growth rate of power consumption increases, the construction of new energy bases such as centralized wind power and photovoltaic power generation and the rapid growth of power generation make the development of China's power grid structure and then enter a new stage [1]. This also requires the power grid to optimize the resource allocation system and capacity through the adjustment of hardware and software, so as to realize the power transmission and consumption in a large region and even in the whole country.

Compared with other developed countries, in terms of grid flexibility and interaction degree, China is currently in a relatively backward level. The intelligent distribution mechanism and two-way interactive service platform of power grid are not mature enough, and also directly reflected in the low level of economic efficiency of smart grid [2]. With the development of economy and society, the progress and innovation of science and technology, the diversity of energy structure and demand side has become more and for the service quality and power quality of the power grid, which makes the power grid strong, economic, reliable, environmental protection, interaction and high efficiency.
development become an important area of power grid development. Therefore, it is of great significance to evaluate the precise investment of power grid and analyze its economic efficiency.

Fuzzy Neural Inference is suitable for solving the problems of high complexity and strong uncertainty by imitating the fuzzy comprehensive judgment in human thinking. After the improvement of Fuzzy Neural Inference, the precision of fuzzy control can be enhanced, the learning rate can be adjusted, and it is more conducive to the establishment of accurate mathematical model [3]. Therefore, on the basis of absorbing the previous domestic and foreign research on the investment evaluation of power grid, this paper constructs the accurate investment evaluation model of power grid based on the Improved Fuzzy Neural Inference, which plays a guiding role in the future development of power grid.

2. Design of accurate investment evaluation model for power grid based on Improved Fuzzy Neural Inference

2.1. Establishment of evaluation index system

Scientific and reasonable power grid investment evaluation index system is the basis of analyzing power grid investment benefits and making targeted investment decisions. The selection of evaluation indexes needs to follow the following principles: systematic principle. The index system is designed in accordance with the systematic principle, striving to fully reflect the overall input-output situation of power grid investment projects. There are not only comprehensive indexes to reflect the overall situation of regional power grid, but also hierarchical indexes to reflect the improvement of each attribute [4]. According to the principle of operability, in the process of power grid project from investment and construction to later operation, it is not operable to include all the indexes involved in the evaluation system.

The paper takes the power supply quality, power grid structure, equipment level, power supply capacity, power grid benefit and intelligence level as the effect indicators, and selects the load supply capacity, equipment technology level, power grid operation level and grid management level as construction indicators [5]. The basic level index of precision investment evaluation of power grid can be obtained by mining the factors that directly affect the effect index in construction index. Because the grass-roots influencing factors are not equally effective and act on the effect indicators at the same time, there must be primary and secondary [6]. In order to make the constructed index system systematic and concise, and comprehensively consider the feasibility of obtaining the index data, through combing the relevant literature and the current standard procedures, expert scoring and other ways, through in-depth mining of grass-roots index information, a total of 16 indicators are selected from the grass-roots indicators, thus establishing a three-tier index system for accurate investment evaluation of power grid, as shown in Figure 1. This index system takes the investment benefit of power grid as the core evaluation target, and reflects the overall target through the three-layer structure of target layer, criterion layer and index layer.
Through the hierarchical classification of power grid investment evaluation index system, covering the multi-attribute indicators of power grid operation, the overall benefit and local input-output of power grid can be effectively and accurately evaluated.

2.2. Membership function design algorithm based on Improved Fuzzy Neural Inference

According to the analysis of accurate investment evaluation of power grid, the improvement of power grid investment benefit is the result of joint action and decision of multiple project attribute investment [7]. In practical engineering, due to the complexity and uncertainty of the research object and the subjectivity and fuzziness of human thinking, decision information is usually expressed as fuzzy information, also known as fuzzy multi-attribute decision. In order to make fuzzy multi-attribute decision, it is necessary to design membership function algorithm to determine the type and specific value of index [8]. However, the increase of the number of nodes will inevitably lead to the increase of the parameters to be learned, thus reducing the learning speed of fuzzy neural network. In this regard, it needs to be improved [9].

The corresponding value of each neuron node in the fuzzy rule layer can be regarded as the possibility of the occurrence of the fuzzy rule, which can also be called the membership degree of the rule layer. Making appropriate fuzzy rule layer can make the result deduced by fuzzy neural network more reasonable and more practical. To solve this problem, the whole rule layer matrix is divided into different classes according to the numerical value, and all the nodes that belong to the same class with the minimum value are the points that we are looking for with "less information". The specific steps of membership function algorithm based on fuzzy clustering principle are as follows:

The first step is to establish the data matrix. The data features are extracted from the samples to be classified, and the original data matrix is obtained.

The second step is data standardization. It is often inconvenient to compare the original data because of different dimensions. In order to solve the problem caused by dimensions, we should standardize the original data, so that different data sets can be compared.

The third step is to establish the fuzzy similarity matrix. The similarity coefficient of each element is determined. The calculation formula is as follows:

$$d(w_i, w_j) = \sum \sqrt{(w_{im} - w_{jm})^2} (1)$$

In formula (1), $d(w_i, w_j)$ is the Euclidean distance between two elements $w_i, w_j$; $m$ is a subset of samples. The Euclidean distance is used to judge the similarity between different elements.
The fourth step is clustering. The result of fuzzy clustering is related to the threshold value, and each threshold value will get the corresponding classification result. According to the actual needs to determine a threshold value range, and then the threshold value in this range gradually from large to small, and finally the various clustering results are compared, in order to get the best fuzzy reasoning results. Through the above steps, the goal of adjusting membership function parameters and fuzzy rules is achieved.

2.3. Setting weight attribute to build accurate investment evaluation model of power grid
The weight coefficient reflects the importance of the impact of each index on the target index in the evaluation index system. Setting a reasonable weight coefficient can ensure the credibility of the evaluation conclusion. In order to make full use of the experience of decision-makers and reflect their preference information, and considering the uncertainty of expert evaluation, this paper uses entropy weight method to calculate the weight of each index. The calculation formula of index entropy is as follows:

$$r_y = -\frac{1}{\lg l} \sum_{x=1}^{l} e_{xy} \ln e_{xy} \quad (2)$$

In formula (4), $y$ is the evaluation index; $r_y$ is the entropy value of evaluation index; $x$ represents the evaluation scheme; $l$ represents the number of evaluation schemes; $e_{xy}$ refers to the proportion of evaluation scheme. According to the entropy value of the evaluation index, the weight of the evaluation index can be obtained. The calculation formula is as follows:

$$w_y = \frac{1-r_y}{\sum_{y=1}^{k} (1-r_y)} \quad (3)$$

In formula (3), $w_y$ represents the weight of evaluation index; $k$ is the number of evaluation indicators. According to the basic level index score of the evaluation object, the final comprehensive evaluation score of power grid investment benefit is calculated by using the analytic hierarchy process. The evaluation model is used to comprehensively evaluate the investment benefits of power grids in various regions, and the ranking analysis of the evaluation results can grasp the leading or backward status of power grid construction in various regions, as well as the relatively complete and weak direction of distribution network construction in specific regions. Based on the above process, the accurate investment evaluation model of power grid based on Improved Fuzzy Neural Inference is completed.

3. Experiment

3.1. Experimental preparation
This experiment is based on the planning report data reported by 11 local and municipal power grids under the jurisdiction of a province, statistics the basic data of individual indicators, calculates the weight of each type of indicators, and the weight assignment results are shown in Table 1.

| Target layer | Criterion layer | Weight | Index layer | Weight |
|--------------|-----------------|--------|-------------|--------|
|              | Power supply quality | 0.23  | Power supply reliability | 0.65  |
|              | Power grid structure | 0.15  | Comprehensive voltage qualification rate | 0.35  |
|              |                  |        | Line passing rate | 0.37  |
|              |                  |        | Transmission rate | 0.48  |
|              |                  |        | Average supply radius | 0.06  |
|              |                  |        | Interconnection rate of trunk lines | 0.09  |
|              |                  |        | Rate of line cabling | 0.24  |
|              |                  |        | Insulation rate of overhead lines | 0.26  |
|              | Equipment level | 0.14  | Proportion of high loss distribution transformer | 0.27  |
According to the index and weight assignment in Table 1, the evaluation model is established to further analyze the performance of power grid precise investment evaluation model.

3.2. Experimental results and analysis
This paper uses the precise investment evaluation model of power grid constructed in this paper for comprehensive evaluation, and compares the evaluation results with the results of existing evaluation models to verify the effectiveness of the model constructed in this paper. This experiment uses the utilization rate of investment information to measure the evaluation effect of the model, and the comparison results are shown in Table 2.

### Table 2 Comparison results of model investment information utilization rate

| Serial number | Evaluation model of this paper | Utilization ratio of investment information (%) | Existing assessment model 1 | Existing assessment model 2 | Existing assessment model 3 |
|---------------|-------------------------------|-----------------------------------------------|-----------------------------|-----------------------------|-----------------------------|
| 1             | 82.82                         | 76.19                                         | 68.36                       | 73.26                       |
| 2             | 84.74                         | 74.41                                         | 69.43                       | 74.37                       |
| 3             | 85.76                         | 75.32                                         | 68.49                       | 75.48                       |
| 4             | 83.58                         | 74.55                                         | 67.57                       | 74.29                       |
| 5             | 84.49                         | 73.48                                         | 70.51                       | 73.08                       |
| 6             | 85.63                         | 72.14                                         | 68.26                       | 75.69                       |
| 7             | 84.15                         | 71.16                                         | 67.21                       | 76.71                       |
| 8             | 83.64                         | 75.19                                         | 69.08                       | 75.34                       |
| 9             | 85.37                         | 74.22                                         | 70.11                       | 74.91                       |
| 10            | 86.28                         | 74.37                                         | 70.69                       | 73.66                       |
| 11            | 84.16                         | 73.09                                         | 71.34                       | 74.34                       |

According to the comparison results in Table 2, the average utilization rate of investment information of the design model is 84.60, and the average utilization rate of investment information of the existing models is 74.01%, 69.20% and 74.65% respectively. The above results show that the design model has certain advantages in the utilization rate of investment information, which is 10.59%, 15.40% and 9.95% higher than the existing models. It proves that the accurate investment evaluation model of power grid constructed in this paper is closer to the actual situation, has high information utilization rate, and can accurately evaluate the benefits of power grid investment projects.

4. Conclusion
In this paper, based on the Improved Fuzzy Neural Inference, the accurate investment evaluation model of power grid is designed. The experimental results show that compared with the existing evaluation model, the model has higher utilization rate of investment information and makes the evaluation results more suitable for the actual situation. Due to my limited ability, there are still some deficiencies in this study, which need to be improved. As the accurate investment of power grid also involves investment risk and other sensitive factors, investment sensitivity analysis can be added to the model to determine the risk aversion strategy, further control the investment risk of power grid and improve the investment efficiency.

References
[1] Wang J. Construction of Risk Evaluation Index System for Power Grid Engineering Cost by Applying WBS-RBS and Membership Degree Methods[J]. Mathematical Problems in Engineering, 2020, 2020(5):1-9.
[2] Jha A P, Singh S K . Performance evaluation of Indian states in the renewable energy sector for making investment decisions: A managerial perspective[J]. Journal of Cleaner Production, 2019, 224(JUL.1):325-334.
[3] Sharma S M, Dasgupta S, Kartikeyan M V. A Hybridized Fuzzy-Neural Predictive Intelligent (HFNPI) Modelling Approach- based Underlap FinFET Model[J]. IETE Journal of Research, 2019, 65(6):771-779.

[4] Hongze, Li, Bingkang, et al. Evaluating the Regulatory Environment of Overseas Electric Power Market Based on a Hybrid Evaluation Model[J]. International Journal of Fuzzy Systems, 2020, 22(1):138-155.

[5] Javadi M S, Razavi S E, Ahmadi A, et al. A novel approach for distant wind farm interconnection: Iran South-West wind farms integration[J]. Renewable Energy, 2019, 140(SEP.):737-750.

[6] Haramaini Q, Setiawan A, Damar A, et al. Economic Analysis of PV Distributed Generation Investment Based on Optimum Capacity for Power Losses Reducing[J]. Energy Procedia, 2019, 156:122-127.

[7] Alsharif M H, Younes M K. Evaluation and Forecasting of Solar Radiation Using Time-Series Adaptive Neuro-Fuzzy Inference System: Seoul City as a Case Study[J]. IET Renewable Power Generation, 2019, 13(10):1711-1723.

[8] Amri S, Litifi H, Ayed M B. A Predictive Visual Analytics Evaluation Approach Based on Adaptive Neuro-Fuzzy Inference System[J]. The Computer journal, 2019, 62(7):977-1000.

[9] Maroufpoor S, Maroufpoor E, Bozorg-Haddad O, et al. Soil moisture simulation using hybrid artificial intelligent model: Hybridization of adaptive neuro fuzzy inference system with grey wolf optimizer algorithm[J]. Journal of Hydrology, 2019, 575:544-556.