IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Comprehensive evaluation for active distribution network

To cite this article: Yongjing Hao *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **563** 042087

Comprehensive evaluation for active distribution network

Yongjing Hao, Jiang Qian, Yi Zhao, Zuodong Feng

[1]State Grid Yuncheng Power Supply Company, Shanxi Province, China

153531077@qq.com

Abstract. Recently, the integration of DG (distributed generation) with high penetration and new loads lead to the transformation to active distribution network. Thus, it is necessary to propose a more suitable comprehensive evaluation index system to achieve the scientific evaluation of operation state and the development of active distribution network. This paper presents a new comprehensive evaluation index system for the active distribution network considering the influence of DG and new load. The combined weighting method based on the variable weight theory and the multi-layer fuzzy comprehensive evaluation method based on the improved trapezoidal cloud model is proposed to solve the model. Finally, case study is carried out to verify the validity of the proposed method and provide the reference value for the future development of distribution network.

1. Introduction

The DG owns great randomness and fluctuations as new kinds of generations. The integration of electric vehicles (EV) and electric heating are totally different from traditional loads, which makes the loads uncertain in time and space. Clearly, there are many changes in active distribution network with the integration of DG and new load. Therefore, it is necessary to propose a new evaluation system.

There have been a lot of research results on the evaluation of DG connected to the active distribution network. Based on the actual structure of power network topology, literature [1] studied the influence of wind turbine and photovoltaic generation on power quality, and analyzed the voltage deviation, harmonic distortion, voltage fluctuation and other indexes through the simulation. There are mainly three aspects in the new load evaluation research, development potential evaluation, economic evaluation and benefit analysis. Combined with China's national conditions, literature [2,3] quantitatively analyzed the potential of electric energy substitution based on support vector machine and decoupling theory respectively. Besides, it is still necessary to evaluate the active distribution network with DG and new load systematically and comprehensively. Literature [4, 5] made a comprehensive evaluation of the distribution network with some kinds of DGs from the perspective of economy, service quality, safety and environmental protection. In general, the comprehensive evaluation of distribution network lacks the consideration of the influence of DG and new loads. And the existing evaluations are mainly about the single index, but few about every index of distribution network. There is no scientific and systematic evaluation system for the distribution network integrated with the new load and DG.

This paper proposes a comprehensive evaluation index system for active distribution network considering the characteristics and influence of DG and new load. The combined weighting method based on variable weight theory, and fuzzy comprehensive evaluation method of active distribution network based on improved trapezoidal cloud model are applied to evaluate the comprehensive performance of active distribution network, greatly improving the accuracy of evaluation results. Finally, the case study is carried out to prove the validity of the evaluation index system and evaluation method.

IOP Conf. Series: Materials Science and Engineering **563** (2019) 042087 doi:10.1088/1757-899X/563/4/042087

The conclusion is drawn through the comparison of the current state and future development state of the power grid.

2. Comprehensive evaluation index system

With reference to the existing construction of comprehensive evaluation indexes of distribution networks, a comprehensive evaluation index system for active distribution networks including reliability, safety, quality and technical economy is established. As shown in figure 1, there are three layers in the evaluation index system, the first layer is the target layer; and the second layer is the criterion layer. In this layer, the distribution network is evaluated from the aspects of safety, reliability, quality and technical economy. And the third layer is the index layer, including twelve specific evaluation indexes subordinate to the four aspects in the criterion layer.

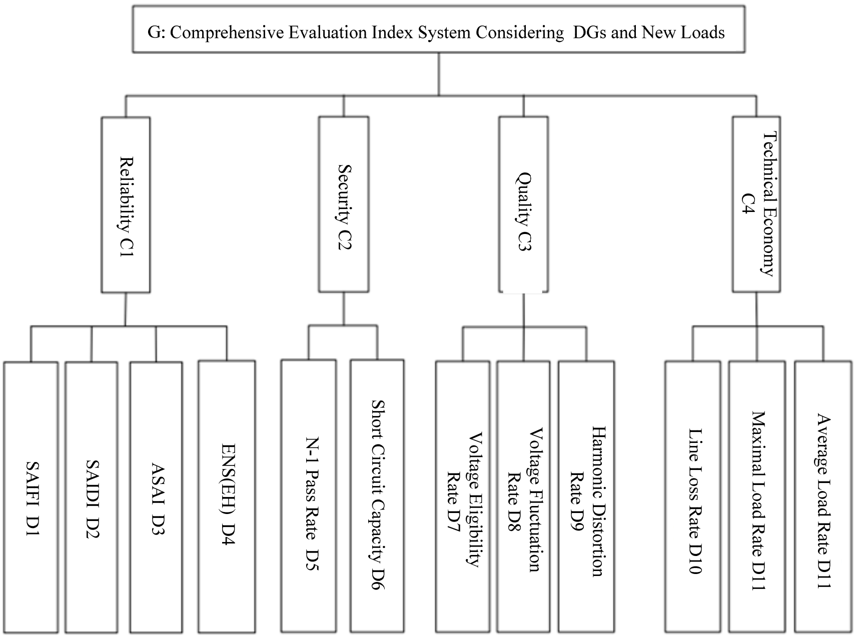

Figure 1. Comprehensive evaluation index system for active distributed network

3. Calculation of comprehensive evaluation index

3.1. AHP model

This paper adopts the combination of the AHP (Analytic Hierarchy Process) and the entropy weight method to obtain a more objective and more scientific result.

The two basic methods of combined weighting method are addition integration and multiplication integration. The multiplication integration could effectively reduce the uncertainty of parameters. The calculation formula of the multiplication integration is as follows.

$$w_j = \frac{w_{Aj} w_{Ej}}{\sum_{i=1}^{n} w_{Ai} w_{Ei}} \tag{1}$$

Here, w_{Aj} and w_{Ej} are weights obtained by AHP and entropy weight method respectively.

The variable weight theory is applied to modify the combined weight to avoid the influence of inaccurate indexes on evaluation. The variable weight calculation formula introduced with the balance coefficient is introduced as follows.

$$w_j = \frac{w_j^{'}\left(x_j\right)^{T_j-1}}{\sum_{j=1}^{m} w_j^{'} S\left(x_j\right)} \tag{2}$$

The formula for calculating the variable weight coefficient is as follows.

$$S\left(x_j\right) = \frac{w_j^{'}\left(x_j\right)^{T_j-1}}{\sum_{l=1}^{m} w_l^{'}\left(x_l\right)^{T_j-1}} \tag{3}$$

Here $w_j^{'}$ is the weight of index j before modification; x_j is the score of index j; $S(x_j)$ is the variable weight coefficient, and T_j is the balance coefficient.

This paper proposes the calculation method for dynamic balance coefficient T_{ij}, to describe the change of T_{ij} with change of the index value under different evaluation schemes, and the formula is as follows.

$$T_{ij} = \min\left\{\frac{\overline{x}_{ij}}{x_{ij}}, \frac{x_{ij}}{\overline{x}_{ij}}\right\} \tag{4}$$

$$\overline{x}_j = \frac{\sum_{j=1}^{m} x_{ij}}{m} \tag{5}$$

Here, $\overline{x}_j$ is the average value of index j under evaluation schemes T_{ij} reflects the degree of the deviation from the average value of index value x_{ij} .

3.2. Fuzzy comprehensive evaluation based on improved trapezoidal cloud model

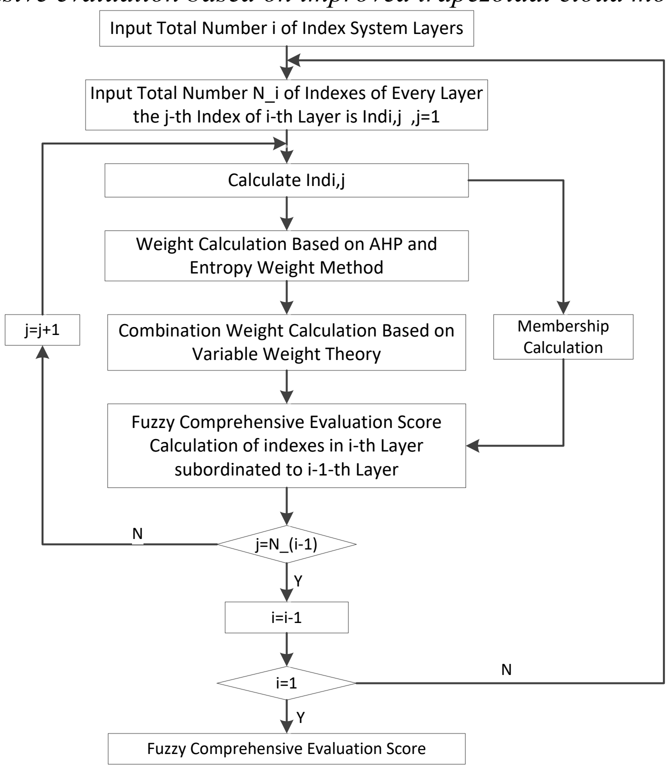

Figure 2. Flow chart of comprehensive evaluation method

Cloud model is an uncertainty transformation model between a certain qualitative concept represented by linguistic value and its quantitative expression. The mapping between quantitative and qualitative expression is composed of expectation E_{x1}, entropy E_n and super entropy He, which is denoted as *Cloud*（E_{x1},E_n ,He）.

Multi-level fuzzy comprehensive evaluation is based on single-level fuzzy comprehensive evaluation. For the evaluation system established in this paper, there are 2 steps in the evaluation process.

Firstly, single level fuzzy comprehensive evaluation is applied in each index to obtain the quantitative fuzzy comprehensive evaluation results;

Then, the single level fuzzy comprehensive evaluation is adopted for each index in criterion layer to obtain the multi-level fuzzy comprehensive evaluation results.

4. Case study

In this paper, a typical urban distribution network is selected to verify and analyze the comprehensive evaluation model for active distribution network integrated with DG and new load. The simplified system is shown in figure 4-1, and the line parameters are taken from literature [7].

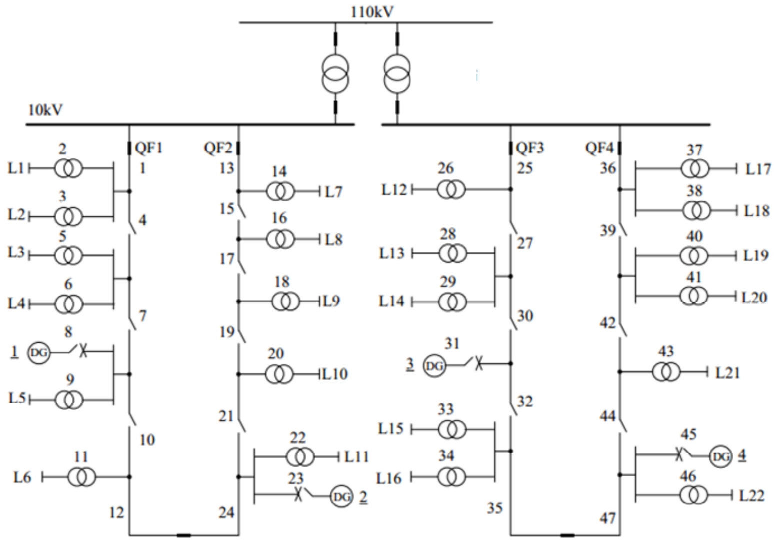

Figure 3. A typical active distribution network integrated with DG and new load

The distribution of DG is shown in figure 3 and table 3.

Table 1. The access position and capacity of distributed generation

DG	Type	Capacity(kW)
1	WT	335
2	PV	500
3	PV	500
4	WT	670

It is assumed that the fault parameters of components such as lines and circuit breakers are always the same, and the fault of DG should be considered in the calculation[9]. Failure rates of various components are shown in table 4.

Table 2. The component reliability data

Component	λ	μ
Line (per km)	0.050	4
Transformer	0.015	200
Breaker	0.002	4
WT	0.050	35
PV	0.050	32

Besides, the influence of new integration of DG and new load should be considered. In the next five years, there would be a stable increase in the capacity of installed DG. The penetration will reach up to 35% till 2022 if it increases 5% per year.

The calculation results of each index are shown in table 5.

Table 3. The results of evaluation indexes

Index	2018	2019	2020	2021	2022
SAIFI (f/a)	0.213	0.211	0.209	0.197	0.195
SAIDI (h/a)	3.13	3.12	3.09	3.04	2.97
ASAI (%)	99.95	99.95	99.95	99.96	99.96
ENS(EH) (kW·h)	18.49	17.03	16.92	15.92	14.93
N-1 Pass Rate (%)	100	100	100	75	75
Short Circuit Capacity(MVA)	46.2	58.3	67.2	83.7	107.6
Voltage Eligibility Rate (%)	1.02	1.04	1.09	1.10	1.15
Harmonic Distortion Rate (%)	1.153	1.172	1.204	1.241	1.263
Voltage Eligibility Rate (%)	96.12	95.83	96.54	96.35	96.41
Line Loss Rate (%)	7.24	6.81	6.04	5.78	5.53
Maximal Load Rate (%)	83.6	87.2	92.3	99.7	108.7
Average Load Rate (%)	68.14	70.25	71.33	73.80	76.04

The evaluation results of active distribution network in each year are shown in table 6, and the corresponding radar chart is shown as figure 4.

Table 4. Comprehensive evaluation result

	2018	2019	2020	2021	2022
Reliability	71.20	72.96	75.38	78.60	80.98
Security	79.58	76.74	80.63	73.28	70.42
Quality	85.97	85.67	84.38	82.11	81.81
Technical Economy	80.37	81.80	83.75	83.30	85.40
Comprehensive Score	76.32	77.65	78.24	79.40	80.73

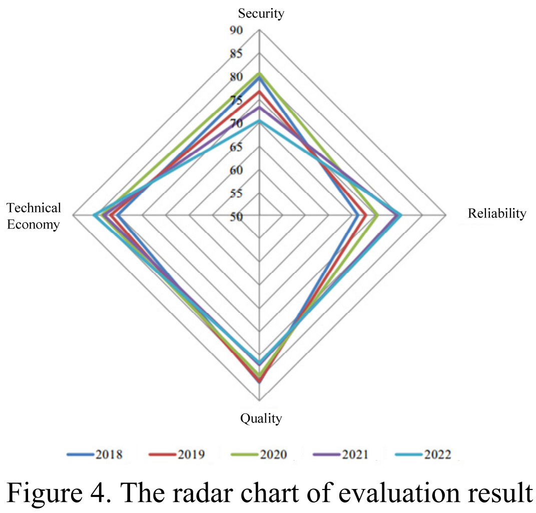

Figure 4. The radar chart of evaluation result

Under the situation that the DG penetration and new loads increases annually, it can be seen from the evaluation results that the reliability score increases, the security score firstly increases and then decreases, the quality score decreases annually, the technical economy score increases annually. The comprehensive score arises when DG and new load develops gradually. Therefore, the integration of DG with a certain penetration contributes to the overall operation level of active distribution network. What's more, the new load helps to consume more distributed generations, improving the quality and technical economy greatly. However, when the scale of integrated DG and new loads reach a certain degree, the security of active distribution network declines due to the uncertainty of DG and new load.

IOP Conf. Series: Materials Science and Engineering **563** (2019) 042087 doi:10.1088/1757-899X/563/4/042087

5. Conclusion

This paper proposes a comprehensive evaluation index system model of active distribution network integrated with DG and new load, based on the existing comprehensive evaluation index system, and the characteristics of DG and new load. The fuzzy comprehensive evaluation method based on combined weighting is presented to solve the proposed model. A typical urban distribution network is selected as the case to prove that the comprehensive evaluation index system is valid, scientific and practical. Meanwhile, the comparison analysis of the comprehensive evaluation results under different development scale of DG provides theoretical basis and practical value for the further research of DG development and power substitution.

References

[1] Luyi K 2017 Power quality analysis research for system integtated with DG
[2] Yi S, Mo S and Baoguo S 2017 *Grid Technology* **41(6)** 1767-71
[3] Yi S, Shuang Z and Baoguo S 2017 *Grid Technology* **41(1)** 118-23
[4] Zhiye C, Yafeng W and Zifa L 2015 *Electricity Construction* **36(1)** 128-35
[5] Peng S, Zhou E and Ji F 2018 Comprehensive evaluation of impacts of distributed generation integration in distribution network
[6] Al-Muhaini M and Heydt G 2013 *IEEE Transactions on Power Systems* **28(3)** 3018-27
[7] Mengyu L AC-DC distribution network evaluation based on improved AHP 2015
[8] Yongji G 2003 *Power System Reliability Analysis* (Tsinghua Publisher)
[9] Zhishan W Reliability evaluation in distribution network considering DG and EV 2016 *Guangdong Industrial University*
[10] Chengshan Q and Xiaoqian S 2012 Power System Automation **36(23)** 54-58