Risk Assessment of Microgrid Based on Credibility Entropy Weight Coefficient Evaluation Model

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Abstract. As a complex network, microgrid must have some weakness. Risk assessment of microgrid will help to find out these weakness so as to put forward the targeted improvement measures and provide strong support for the optimal operation of microgrid. According to the risk assessment of microgrid, this paper establishes a microgrid risk index system, which includes the first-level indexes and corresponding sub-indexes of structural safety, operation safety and technical safety, and innovatively establishes a credibility entropy weight coefficient evaluation model, and calculates the weight of each index layer and the comprehensive risk assessment score of the microgrid. Furthermore, the risk assessment of a microgrid system is analyzed by quantitative calculation in order to make the assessment results more reliable and provide reference for further improving the risk assessment of the microgrid.

Keywords: Microgrid, risk assessment, credibility theory.

1. Introduction
Microgrid is an organic whole composed of distributed power, energy storage/supply service, which plays an active role in improving power supply reliability and power quality. As a complex network, microgrid must have some weakness. Risk assessment of microgrid will help to find out these weakness so as to put forward the targeted improvement measures and provide strong support for the optimal operation of microgrid.

At present, the commonly used methods for risk assessment are the multi-level grey comprehensive evaluation method, the fuzzy comprehensive evaluation method and the neural network evaluation method, which is all has its own shortcomings. For example, the multi-level grey comprehensive evaluation method and the fuzzy comprehensive evaluation method has solved the problem of describing the uncertainty of risk factors, but because of the probability theory, the fuzzy mathematics and the grey system theory are relatively independent branches, it is difficult to fuse them under the same framework. The neural network evaluation method has some shortcomings, such as long training time, difficult to determine the topology of the network, and the training effect is greatly affected by the initial parameters, which makes the reliability of the evaluation results questioned.
Therefore, based on credibility theory, this paper puts forward a credibility entropy weight coefficient evaluation model, which overcomes the defect of the strong subjectivity of traditional method, thus enhancing the credibility of the weight. At the same time, based on the risk assessment of microgrid, the risk assessment index system of microgrid is established by analyzing the risk factors of microgrid, and then the risk of microgrid is quantitatively assessed, and the importance of each risk factor and the risk level of the microgrid system are analyzed.

2. Construction of Risk Assessment Index System of Microgrid

According to the technical standards, management regulations of microgrid, this paper constructs a risk assessment index system of microgrid in accordance with the principles of comprehensive, purposeful and comparable, and the actual situation of microgrid risk evaluation. As shown in figure 1. The index system includes 3 first-level indicators, 7 second-level indicators and 22 third-level indicators.

Figure 1. Comprehensive Index System for Risk Assessment of Microgrid
2.1. Structural safety risk
From the point of view of microgrid structure security, there are mainly the following three risks:

1) Risk of internal grid structure. The internal grid structure is the physical basis for the stable operation of microgrid. In the design of grid structure, failure to properly divide the layers according to voltage level and power supply load density will affect the normal operation of the distributed power supply. In addition, problems in the high and low voltage electromagnetic ring network structure will cause load transfer and may cause the expansion of safety accidents, which should also be considered.

2) Risk of major components. Micropower supply, energy storage device and load are the main components of microgrid, and their configuration is directly restricted by the size of microgrid. Many kinds of distributed power sources such as wind and light in microgrid are affected by the external environment, and unreasonable power supply structure will bring risks. The energy storage device provides emergency power support when switching from parallel to off-grid and alleviates the impact of intermittent distributed power supply on the microgrid. It must be ensured that the energy storage device has sufficient compensation capability. The load itself has fluctuation, which will make the voltage, power and frequency of microgrid fluctuate. Impact load may cause voltage flicker, thermal shock, insulation aging and other problems, affecting the safety of microgrid operation.

3) Risk of Important Power Channels. The power channel connects the power transmitting end and the power receiving end and is the carrier of power transmission. The transmission capacity and possible failures of the channel will affect the safety of the microgrid.

2.2. Operational safety risk
The risk impact of the following two aspects is mainly considered during the operation of microgrid:

1) Self – risk. Microgrid has two modes of operation: grid-connected mode and island mode. When the two modes are switched, the frequency, voltage and power angle of the system will change to different degrees, which may lead to safety risks. In addition, the unplanned island phenomenon that may occur is an unplanned and uncontrolled operation state, which will cause the microgrid to be out of monitoring and thus bring high hidden dangers to the operation. During the operation of microgrid, overload and thermal shock may reduce the reliability of the equipment and affect the safe operation of microgrid. In addition, the harmonic distortion caused by the application of large-capacity power electronic devices in the microgrid may cause interference to the communication system in the microgrid.

2) Risk of external influence. Improper human operation and mistakes in microgrid operation may bring risks to the safe operation of microgrid. In addition, the environment in which the microgrid is located is complex, and natural disasters will have an impact on the safe operation of the microgrid.

2.3. Technical safety risk
In terms of technical safety of microgrid, the following risks are mainly considered:

1) Protect technical risks. Due to the access of a large number of distributed power sources and energy storage devices, microgrid protection devices are different from traditional grid protection in selection and configuration. At the same time, the micro-grid has the characteristics of two-way power flow and large short-circuit current difference between grid-connected and off-grid conditions, which puts forward new requirements for protection technology. These new problems may lead to a series of problems such as reduced fault location capability and misoperation of the protection system.

2) Manage technical risks. Microgrid management technology mainly includes monitoring technology and energy management technology. Monitoring technology monitors the power generation, energy storage and load of microgrid, and monitoring failure will make operators unable to accurately grasp the operation of microgrid. Energy management technology is mainly used to forecast distributed generation and load, and if the forecast deviation is too high, it will affect the dispatching execution, thus affecting the operation of microgrid.
3. Introduction of the Credibility entropy weight coefficient evaluation model

Based on the technical characteristics of microgrid and combined with the latest research result in basic mathematics - credibility theory, this paper innovatively establishes a credibility entropy entropy weight coefficient evaluation model and applies it to the risk assessment of microgrid. This model can better eliminate the shortcomings of the other quantitative evaluation model, such as strong subjectivity, and overcome the shortcomings of fuzzy mathematics membership function, such as lack of self-dual characteristics, and provide a more reliable evaluation result.

3.1. The construction of the credibility evaluation matrix

First, construct a set of microgrid’s risk factors, U, where U= {u1, u2, ..., un}. Then, construct the evaluation set of the situation of each factor V separately, where V= {v1, v2, ..., vm}.

In terms of the credibility inversion theorem:

$$Cr\{v_j = y_i\} = \frac{1}{2} (u_j(y_i) + 1 - \sum_{x \in Y_j} u_j(x)),$$

(1)

Where $u_j(x)$ indicates the membership of $x$ to $v_j$ under the factor $u_i$, $i=1,2,\ldots,n$, $j=1,2,\ldots,m$.

When the fuzzy event $\{v_j=y_i\}$ happens, let $Cr\{v_j=y_i\}$ be the credibility measure of it, that is, when factor $u_i$ values $y_i$’s attribute value, the credibility measure of the event evaluation object belongs to judgement set $v_j$.

Based on the factor set $U$, evaluation set $V$ and the formula (1), the following matrix can be obtained:

$$R=(r_{ij})_{nm} = \begin{pmatrix}
Cr\{v_1 = y_1\} & Cr\{v_1 = y_2\} & \cdots & Cr\{v_1 = y_m\} \\
Cr\{v_2 = y_1\} & Cr\{v_2 = y_2\} & \cdots & Cr\{v_2 = y_m\} \\
\vdots & \vdots & \ddots & \vdots \\
Cr\{v_n = y_1\} & Cr\{v_n = y_2\} & \cdots & Cr\{v_n = y_m\}
\end{pmatrix}$$

(2)

$R$ is called credibility judgement matrix, where $r_{ij}=Cr\{v_j=y_i\}$.

3.2. Determine the entropy weight coefficient of each risk factor

As for risk assessment factor i, according to the extreme value of credibility entropy, the closer the value of $r_{ij}$ (j=1, 2, ..., m), the greater the entropy value, and the greater the uncertainty of risk assessment for microgrid by this factor. Therefore, $r_{ij}$ can be used to calculate credibility entropy and then determine the weight of each index. The specific method is as follows:

1) Calculate the credibility entropy

$$H[r_{ij}] = \sum_{j=1}^{m} S(r_{ij})$$

(3)

Where, $S(r_{ij}) = -r_{ij} \ln r_{ij} - (1 - r_{ij}) \ln (1 - r_{ij})$.

2) Normalization processing

$$\varphi_i = \frac{H[r_{ij}]}{H_{max}} = \frac{\sum_{j=1}^{m} S(r_{ij})}{m \ln 2}$$

(4)

Where, $H_{max} = m \ln 2$.

3) Determine the weight of each index
As the greatest the entropy is, the minimum contribution to the risk assessment of the microgrid, therefore the weights of hazard factors $u_i$ can be measured by $1-\varphi_i$. Weight $\omega_i$ can be expressed as:

$$\omega_i = \frac{1 - \varphi_i}{n - E}, \quad (5)$$

where, $E = \sum_{i=1}^{n} \varphi_i$, $\omega_i$ satisfied $0 \leq \omega_i \leq 1$; $\sum_{i=1}^{n} \omega_i = 1$

### 3.3 Calculation of Comprehensive Evaluation Value

The weight vector $\omega$ and the single index fuzzy evaluation matrix $R$ are combined by fuzzy matrix operation to obtain the comprehensive evaluation matrix $B_i = \omega_i \circ R_i$ of the single-level sub-target, where $\circ$ is the generalized fuzzy multiplier, and the comprehensive evaluation results of the other indexes of the B-level and the indexes of the A-level can be obtained in the same way. Finally, the final evaluation score of the microgrid system is calculated and its risk evaluation effect is determined by setting a score for the evaluation set.

### 4. Empirical Analysis

This paper takes a microgrid system as an example. The system consists of four distributed power sources and is equipped with the energy storage devices, energy conversion devices, protection systems, analog controllable loads and micro-grid SCADA monitoring systems.

According to the evaluation system and model established in chapters II and III, combined with the actual situation of the project, the risk evaluation of the microgrid system is as follows.

#### 4.1 Set up comment sets

According to the actual situation of microgrid risk assessment and the characteristics of the established assessment indicators, the expert's comments on each level of indicators are summarized as {Excellent, Better, General, Poor}.

#### 4.2 The determine of the fuzzy membership matrix and the redibility judgement matrix $R$

Taking the evaluation of internal grid structure as an example, through the questionnaire survey, the collected data can be sorted out, and the degree of membership of each factor in this level can be obtained, that is the determine of the fuzzy membership matrix $R_{A_{ii}}$, as follows:

$$R_{A_{ii}} = \begin{bmatrix} 0.47 & 0.31 & 0.17 & 0.05 \\ 0.29 & 0.38 & 0.21 & 0.12 \\ 0.49 & 0.21 & 0.13 & 0.17 \end{bmatrix}$$

According to the credibility inversion theorem, i.e. formula (1) and the fuzzy membership matrix $R_{A_{ii}}$, the redibility judgement matrix $R$ of internal grid structure can be obtained, as follows:

$$R_{A_{ii}} = \begin{bmatrix} 0.58 & 0.42 & 0.35 & 0.29 \\ 0.64 & 0.36 & 0.32 & 0.34 \\ 0.64 & 0.36 & 0.28 & 0.24 \end{bmatrix}$$

#### 4.3 Determination of Evaluation Index Weight

The entropy weight coefficient $\varphi_i$ of each factor obtained from the credibility judgment matrix $R_{A_{ii}}$, and formula (4) is as follows:

$$\varphi_{A_{ii}} = (0.94 \ 0.92 \ 0.88)$$

Then, the weight of each factor can be obtained from equation (5):
The weights of the other factors can be obtained according to the steps and methods above, which are not listed here, and the calculation results are shown in fig. 1.

4.4. Comprehensive Evaluation of Single Subobjective

On the basis of obtaining the fuzzy membership matrix, the fuzzy relationship between the fuzzy membership matrix and the weight vector is synthesized as follows:

\[ C_{ii} = \omega_{\theta_{i1} \cdots \theta_{in}} \circ R_{\theta_{i1} \cdots \theta_{in}} \]
\[ = (0.24 \ 0.29 \ 0.47) \]
\[ \times (0.47 \ 0.31 \ 0.17 \ 0.05) \]
\[ = (0.42 \ 0.28 \ 0.16 \ 0.13) \]

The factors of each layer are calculated as above, and in the same way:

\[ B_i = (0.31 \ 0.37 \ 0.21 \ 0.11) \]
\[ B_j = (0.21 \ 0.33 \ 0.25 \ 0.21) \]
\[ B_k = (0.32 \ 0.24 \ 0.33 \ 0.10) \]

Thus, the evaluation result of the evaluation index of layer A can be obtained as follows:

\[ A = \omega_{B_i \cdots B_k} \circ R_{B_i \cdots B_k} \]
\[ = (0.33 \ 0.38 \ 0.29) \]
\[ \times (0.37 \ 0.31 \ 0.21 \ 0.11) \]
\[ = (0.33 \ 0.32 \ 0.22 \ 0.13) \]

4.5. Comprehensive evaluation score

Let common set V= \{Excellent, Better, General, Poor\} = \{100, 80, 60, 40\}, then the comprehensive risk evaluation score of the microgrid system is:

\[ U = 0.33 \times 100 + 0.32 \times 80 + 0.22 \times 60 + 0.13 \times 40 \]
\[ = 77 \]

The evaluation result is close to the "better" level of 80 points, so its comprehensive evaluation of risk is "better". This shows that the microgrid system is relatively safe, but there is still room for improvement. Relevant departments still need to take measures to further strengthen the overall security of the microgrid.

5. Conclusion

In this paper, a microgrid risk index system is established for its security risk assessment. At the same time, based on credibility theory, a credibility entropy weight coefficient evaluation model is proposed. The model uses information entropy weight to determine the weight of the factor, which can objectify the results of subjective analysis, thus enhancing the credibility of the weight. Based on this, and then, an example is analyzed. The analysis results show directly the importance of the three major risks in microgrid, and also get the importance ranking of the sub-indicators of the three major risks. In addition, according to the final evaluation results, the security risk of the microgrid system is at a medium level and there is a great room for improvement.
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