Study of Comprehensive Evaluation Method on NIMBY Syndrome Based on Improved Radar Chart for Power Grid Project

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Abstract. In order to slow down the serious NIMBY (Not In My Back Yard) syndrome on power grid project, maintain stable development of power grid and social harmony, this paper establishes a reasonable and scientific NIMBY risk comprehensive evaluation system of power grid project. Comprehensive NIMBY factors that affect power grid project is proposed. Making quantitative analysis to NIMBY syndrome on the basis of improved radar chart and improved AHP (Analytic Hierarchy Process). The improved radar chart supplies the gap that traditional radar chart evaluation result is not unique, the improved AHP does not need consistency check and it can reduce calculation amount apparently and simplicity. Finally, example analysis of different substations verifies the rationality and feasibility of the proposed evaluation system, it shows that this system can provide scientific basis for the facility siting and governance of risk in power grid project.

Introduction

China’s economy has been in a stage that changed from rapid growth to high-quality development, State Grid proposes to build a world-class strong smart grid. However, with the rapid construction of a strong power grid that build a strong ultra-high voltage grid as the backbone network and coordinated development of power grids at all levels, NIMBY (Not In My Back Yard) syndrome on power grid project is obvious, environment disputes are increasing year by year, grid construction blocked, excessive rights of residents and so on happen from time to time in some regions, it affect the normal development and construction of power grid[1].

The NIMBY index of different infrastructure is quite different, so it is necessary to evaluate NIMBY syndrome on power grid project to ensure the safe and stable operation. Research has now mainly focus on conception, cause and coping strategy [2-4], NIMBY risk factors lack quantitative analysis and comparison, it is hard to grasp risk characteristics entirely and reflect the interaction and influence between factors effectively.

Comprehensive Evaluation Index of NIMBY Risk on Power Grid Project

According to the research on the risk characteristics of power grid project and the principles of scientific and comprehensiveness to select indicators, combing experts and public opinions, the paper establishes a comprehensive evaluation index system of NIMBY risk on power grid project.

The system includes eight first class indexes as public anti-risk capability, public perception, compensation degree, impact of power grid project, location, trusted degree of electric power company, government credibility, publicity and communication, on this basis, we choose second class indexes that represent and reflect various kinds of NIMBY factors as shown in table 1. These factors can reflect NIMBY effect of power grid project entirely [5]. According to the effect of NIMBY, the values of NIMBY factors ranging from large to small are 5~1, public questionnaires and expert consultation are used to evaluate the scores. Then using statistical method to process the data and obtaining NIMBY index of each factor.
Table 1. Comprehensive evaluation index of NIMBY risk.

| First-class indexes | Second-class indexes |
|---------------------|----------------------|
| Public anti-risk capability (A) | Annual income level (A1) |
|                       | Presence of children (A2) |
|                       | Residential mobility (A3) |
|                       | Education level (A4) |
| Public perception (B) | Knowledge of risk factors (B1) |
|                       | Expectations of life (B2) |
|                       | Access to facility information (B3) |
|                       | Knowledge of correct scientific concepts (B4) |
| Compensation degree (C) | Willingness to accept (C1) |
|                       | Willingness to pay (C2) |
| Impact of power grid project (D) | Influence of noise (D1) |
|                       | Degree of radio interference (D2) |
|                       | Inductive magnitude (D3) |
|                       | Degree of environmental pollution (D4) |
|                       | Strength of the power frequency magnetic field (D5) |
| Location (E) | Population density (E1) |
|                       | Span scope (E2) |
|                       | Distance from the city center (E3) |
| Trusted degree of electric power company (F) | Trusted degree of electric power company (F1) |
| Government credibility (G) | Government credibility (G1) |
| Publicity and communication (H) | Media direction (H1) |
|                       | Public participation (H2) |
|                       | Information transparency (H3) |

**Improved AHP Determine Index Weight**

Analytic Hierarchy Process (AHP) is the one which conjoint the determine the nature method and quantitative analysis, which was formally proposed by T. L. Saaty in 1970 [6]. AHP stratifies complex problem virtually on the basis of artificial judgement, then ranks decisions according to their merits. The traditional AHP method under the condition of multi-order judgment tend to have inconsistent thinking, in this condition, we need to judge the matrix consistency test, in case of inconsistency, the judgment matrix needs to be revised until it meets the consistency requirement. This method is complex and requires a lot of calculation. The judgment matrix determined by this method does not need consistency check and can determine the weight of the first and second index directly [7].

**Constructing Judgment Matrix**

Judgment matrix $M=(m_{ij})$ established by AHP satisfies the following conditions: ①$m_{ij}>0$; ②$m_{ij} = 1 / m_{ji}$; ③$m_{ij} = m_{ik} \times m_{kj}$. ($i$, $j$, $k$ = 1, 2, ..., $n$). $m_{ij}$ represent the scale value that the i-th element compared to the j-th element. Detailed meaning is shown in table 2.

$$M = \begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1j} \\ m_{21} & m_{22} & \cdots & m_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ m_{i1} & m_{i2} & \cdots & m_{ij} \end{bmatrix}$$
Table 2. The meaning of each scale value.

| Scale | Implication                                      |
|-------|-------------------------------------------------|
| 1     | Both elements are equally important             |
| 1.2   | One element is slightly more important than the other |
| 1.4   | One element is significantly more important than the other |
| 1.6   | One element is highly more important than the other |
| 1.8   | One element is extremely more important than the other |
| Reciprocal of the above scale | Element i compares to element j to get \( m_{ij} \), then element i compares to element j to get \( m_{ji} = 1/m_{ij} \) |

According to the opinions of experts and the public, pairwise comparisons are made on the factors of NIMBY in power grid project, ranking according to their importance, let the order of importance of \( n \) indicators is \( X_1 \geq X_2 \geq \ldots \geq X_n \), comparing \( X_i \) with \( X_{i+1} \) and the corresponding scale value is denoted as \( r_i \). The values of other elements in the matrix are determined according to the transitivity of the important degree of the index, then we get the judgment matrix \( R \).

\[
R = \begin{bmatrix}
1 & r_1 & r_2 & \cdots & r_{n-2} & r_{n-1} \\
1/r_1 & 1 & r_3 & \cdots & r_{n-2} & r_{n-1} \\
1/r_2 & 1/r_3 & 1 & \cdots & r_{n-2} & r_{n-1} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
1/r_{n-2} & 1/r_{n-3} & 1/r_{n-4} & \cdots & 1 & r_{n-1} \\
1/r_{n-1} & 1/r_{n-2} & 1/r_{n-3} & \cdots & 1/r_{n-2} & 1 \\
\end{bmatrix}
\]

Weight Calculation

Matrix \( R \) combines with formula (1) to calculate the weight of each index \( w_i \). The weights of primary and secondary indicators are \( w_{i1} \) and \( w_{i2} \) respectively.

\[
w_i = \sqrt{\prod_{j=1}^{a} m_{ij}} / \sum_{i=1}^{n} \sqrt{\prod_{j=1}^{a} m_{ij}} \quad (0 \leq w_i \leq 1).
\] (1)

Quantitative Comprehensive Evaluation of Improved Radar Chart

Drawing a Radar Chart

The radar chart, which is a typical graphical evaluation method, is used for the qualitative evaluation, and is as the quantitative evaluation by extracting the characteristic vector and constructing evaluation vector and evaluation function [8]. The traditional radar chart method is simple and intuitive, but it has some problems. On the one hand it does not consider the interaction between factors, on the other because of the different order of factors, different radar images are obtained and different evaluation results are produced. Therefore, the paper presents an improved radar chart method, which combines image and quantitative analysis.

Drawing standard round, the central O leads to line segment OA, length 5, starting with OA and rotating the angle \( \theta (\theta = w_i \times \pi) \) clockwise in turn, turning into line segment (OB, OC, OD, OE...), these segments divide the circle into \( n \) sectors, taking the angular bisector of each sector (OP_1, OP_2, OP_3, OP_4, OP_5...) as the index axis. The corresponding points are marked on the index axis by the NIMBY factor \( X_i \) (i=1,2, \ldots n), connecting all points in sequence, then the improved radar chart will be obtained, as shown in figure 1.
Calculating the Comprehensive Evaluation Index

\[ v_{i1} = \frac{S_i}{S_{\text{min}}} \]  
\[ v_{i2} = 4\pi \frac{S_i}{L_i^2} \]  
\[ f_o = \sqrt{v_{i1} \times v_{i2}} \]  

In the formula (2) ~ (3), \( S_i \) and \( L_i \) represent the sum of the area and perimeter of the radar map corresponding to the evaluation object, \( S_{\text{min}} \) represents the total area of radar chart corresponding to the most balanced object, \( v_{i1} \) and \( v_{i2} \) represent the estimated area and perimeter, the higher the value \( (v_{i1}) \) is, the lower the overall level of the evaluation object index, and vice versa. The greater the value \( (v_{i2}) \) is, the more unstable the development of each factor of the evaluation object is, and vice versa. Formula (4) is the constructed first-class index evaluation function, \( f_o \) is the evaluation value of the first-class index.

According to formula (5), the evaluation value of the first-class index and their weights are weighted and summed, then we will obtain the comprehensive evaluation value \( (f) \) of the evaluation object. The higher the value \( (f) \), the NIMBY risk index is higher in the area and special attention should be paid to the area.

\[ f = \sum f_o \times w_{i2} \]  

Example Application

Taking Wuhan substation and Jingzhou substation as examples, the algorithm analysis is carried out, verifies the feasibility of the proposed algorithm.

Both substations are built in densely populated areas, adjacent to community kindergartens and other public areas, which are opposed by residents to varying degrees. There are some outstanding problems in the Wuhan substation, such as the weak risk tolerance of the nearby residents, the lack of public trust of the government and the power company, and the insufficient publicity and communication, the noise of the substation also affects the daily life of the residents. The public in the vicinity of the substation do not have a good understanding of the information of the substation, there are some misconception of the correct scientific concept, and there are some problems with the media orientation.

According to the situation of these two substations, the risk index of each factor is given in table 3 through public survey and expert rating. According to formula (1)~(4), the weight of the second class indexes \( (w_{i1}) \) and the evaluation value of the first class indexes \( (f_o) \) can be calculated. According to formula (5), the comprehensive evaluation value of the two substations can be calculated, as shown in table 4.
Table 3. Secondary index evaluation of two substations.

| Second class index | Weight $w_{ij}$ | Angle $\theta$ (°) | Wuhan substation | Jingzhou substation | $f_{ij}$ | $f_{ij}$ |
|--------------------|-----------------|---------------------|------------------|---------------------|---------|---------|
| A1                 | 0.178           | 63.920              | 4.11             | 3.73                |         |         |
| A2                 | 0.332           | 119.659             | 4.47             | 4.06                | 0.862   | 0.906   |
| A3                 | 0.277           | 99.716              | 4.16             | 3.77                |         |         |
| A4                 | 0.213           | 76.705              | 4.02             | 3.65                |         |         |
| B1                 | 0.288           | 103.616             | 4.04             | 3.67                |         |         |
| B2                 | 0.185           | 66.421              | 3.74             | 3.39                | 0.924   | 0.892   |
| B3                 | 0.240           | 86.347              | 3.48             | 3.36                |         |         |
| B4                 | 0.288           | 103.616             | 4.06             | 4.42                |         |         |
| C1                 | 0.545           | 196.364             | 3.65             | 3.81                | 0.865   | 0.848   |
| C2                 | 0.455           | 163.636             | 3.37             | 3.06                |         |         |
| D1                 | 0.200           | 72                  | 3.91             | 3.55                |         |         |
| D2                 | 0.200           | 72                  | 3.22             | 2.92                |         |         |
| D3                 | 0.200           | 72                  | 3.12             | 2.83                | 0.886   | 0.812   |
| D4                 | 0.200           | 72                  | 3.54             | 3.21                |         |         |
| D5                 | 0.200           | 72                  | 4.08             | 4.21                |         |         |
| E1                 | 0.353           | 127.059             | 4.17             | 4.28                |         |         |
| E2                 | 0.294           | 105.882             | 3.69             | 3.35                | 0.882   | 0.943   |
| E3                 | 0.353           | 127.059             | 3.49             | 3.67                |         |         |
| F1                 | 1               | 360                 | 4.49             | 4.08                | 1       | 1       |
| G1                 | 1               | 360                 | 4.23             | 3.84                | 1       | 1       |
| H1                 | 0.294           | 105.882             | 4.45             | 4.04                |         |         |
| H2                 | 0.353           | 127.059             | 4.36             | 3.96                | 0.989   | 0.925   |
| H3                 | 0.353           | 127.059             | 4.19             | 3.80                |         |         |

Table 4. Comprehensive index of two substations.

| First class index | Weight $(w_{ij})$ | Angle $\theta$ (°) | Wuhan substation ($f_i$) | Jingzhou substation ($f_j$) |
|-------------------|-------------------|---------------------|--------------------------|-----------------------------|
| A                 | 0.198             | 71.28               |                          |                             |
| B                 | 0.165             | 59.4                |                          |                             |
| C                 | 0.150             | 54                  |                          |                             |
| D                 | 0.125             | 45                  |                          |                             |
| E                 | 0.104             | 37.44               | 0.914                    | 0.907                       |
| F                 | 0.104             | 37.44               |                          |                             |
| G                 | 0.087             | 31.32               |                          |                             |
| H                 | 0.068             | 24.48               |                          |                             |

We can see from table 4, the comprehensive evaluation values of the two substations are $f_i=0.914$, $f_j=0.907$ respectively, both substations have NIMBY risk, but Wuhan substation has higher risk.

Taking Wuhan substation as an example, strengthening the management of risk index and factors with high weight before, during and after the construction of the substation, and formulating the risk response mechanism of NIMBY. Such as propaganda and communication, Wuhan substation is weak, the government and the electric power company should actively communicate with the public, popularize the science of electromagnetism, establish information disclosure mechanism, etc., to achieve further understanding of the public.

In the actual situation, after the construction of the substation was blocked, the power company and the government actively coordinated and communicated with each other, invited residents to visit the substation, enhanced the publicity of popular science, and made efforts to improve the credibility. Optimizing the layout and construction style of substation and cable access scheme, winning public understanding and trust in a scientific, reasonable and credible way.

Therefore, the comprehensive evaluation system established in this paper is in good agreement with the actual situation. The evaluation system can also be used in the selection period of substation, estimate and compare the risk of NIMBY at different locations, choose the appropriate address, and control in advance to minimize the risk.
Summary
The paper establishes a comprehensive and reasonable evaluation system for NIMBY risk in power grid project. Improved radar chart and improved AHP evaluate NIMBY risk quantitatively and evaluating the risk indexes according to the weight of all levels of indicators. It provides scientific basis for the facility siting and countermeasure of NIMBY effect. We can take more targeted measures and has an inhibitory effect on the generation of NIMBY effect in power grid project. It also can be widely used in other NIMBY facilities and maintain the stable development of society.

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