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Study on Influence Factors of Distributed Energy System Based on DEMATEL and ISM

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Abstract: Distributed energy system has got more attention from the international community. But distributed energy has just begun to develop in China and it is important to reasonablely master its influence factors. DEMATEL and ISM methods are applied to find the most important factors and the relationship of all the factors. The synthesized conclusion from the two methods is that social recognition, laws and regulations, production cost have the direct impact on the development of distributed energy. But the factors with the greatest impact on distributed energy are grid-connected technology and technology maturity, which are the most fundamental problems to be solved currently.

Keywords: distributed energy system; DEMATEL; ISM; influence factors

1 Introduction

Since the energy crisis, all countries are concerned about the future energy problems. The coordinated and sustainable development of energy, economic, and environmental has become a common goal. Distributed energy systems (DES) offers a number of potential benefits compared with traditional centralized power generation, such as increased supply quality and security, reduced environmental pollution, higher energy efficiency, lower transmission and distribution losses, etc. (DES) is believed to be a useful complement for power grids and getting more and more attention[1-5]. In [6], a genetic algorithm is applied to plan and design (DES). In [7], a simultaneous consideration of the thermodynamic, economic and emission criteria of (DES) in an urban residential area in Beijing has been realized through thermo-economic optimization. In [8], a model for structural and operational optimisation of (DES) is presented to research the problem of production and consumption of electrical power. [9] models the diffusion of DER in the US commercial building sector under various technical research and technology outreach scenarios.

The above results have an important significance in the development of (DES). But (DES) is still in its infancy in China and facing many difficulties and obstacles. Identifying the key influence factors is the primary task for (DES)'s development. There are scholars at home analyse factors in different aspects[10], but the results are qualitative and it's difficult to distinguish between primary factors and secondary factors. Therefore, the paper utilizes DEMATEL and ISM methods to discuss the influence factors quantitatively in connection with China's actual conditions. Primary factors and relationship of various factors are clarified by the two mathods and the conclusion can provide a reference for (DES)'s development in China.

2 Analysis of influence factors of (DES)

For many years, electricity market in China is a Power Grid Corporations monopoly. The situation will be undermined by (DES). According to foreign experience and China's actual situation, (DES)'s development needs policy support, especially in the early stages of its development. After entering the market, (DES) needs to overcome its technical barriers

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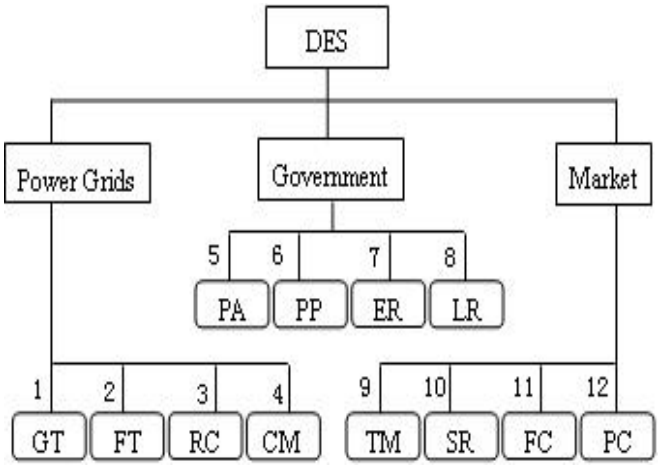
and consider a series of grid-connected issues about technique and management. Therefore, (DES)'s development is not a simple problem of technology introduction, but a complexity problem that needs to consider numerous factors from power grids, government and market.

Main influence factors from power grids, government and market are extracted according to the available researches of literatures and investigations[11-14]. Feed-in tariff, restructure cost, grid-connected technology and cooperation management can be seen as the most concerned issuses for the cooperation between (DES) and power grids. Government's initiatives such as preferential policies, laws and regulations, electricity regulation and permit approval play an important role in the development of (DES). Technology maturity, social recognition, financing channel and production cost are the challenges (DES) receives in the market environment. Key influence factors system of (DES) is summarized in Figure 1.



GT: grid-connected technology FT: feed-in tariff RC: restructure cost
CM: cooperation management PA: permit approval PP: preferential policies
ER: electricity regulation LR: laws and regulations TM: technology maturity
SR: social recognition FC: financing channel PC: production cost

Figure 1: Influence factors system of (DES).

In order to clarify relationship of various factors in the factors system, a questionnaires is designed and distributed to30 experts by e-mail, including power grids staff, government officials and (DES) technical staff. Proportion of survey personnel is 30%, 30% and 40%. 30 questionnaires were sent and 26 valid questionnaires were returned. Recovery percent is 86.7%. Influence relationship between every two factors is shown in Table 1. If more than 50% results believe there are direct influence between two factors, the corresponding element value is 1, otherwise it is 0..

Table 1: Relationship of the influence factors of (DES)

factor	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	1	0	0	0	1	1	0	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	0	0	1	0	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0	1	0	1	0	0
5	0	0	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	1	0	1
7	0	0	0	0	0	1	0	1	0	0	0	1
8	0	1	0	0	1	0	0	0	0	1	0	0
9	1	0	0	0	0	0	0	0	0	1	0	1
10	0	0	0	0	1	0	0	1	0	0	1	0
11	0	0	0	0	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	0	1	0	0

3 Analysis of key factors based on DEMATEL method

3.1 Direct influence matrix

According to Table 1, direct influence matrix is represented by a n-order matrix $X = \left(a_{ij}\right)_{n\times n}$, where a_{ij} denotes the influence relationship between factor i and factor j. $a_{ij} = 1$ means that factor i has a direct impact on factor j, otherwise the element value is 0. In order to ensure computing convergence, regularization matrix is composed by the matrix elements divided by the maximum of summation of each row of matrix.

3.2 Combined influence matrix

In order to analyze mutual relationship between factors, combined influence matrix is calculated, which is represented by Eq. (1).

$$T = X + X^2 + ... + X^n = X(I - X)^{-1} \tag{1}$$

According to the elements of matrix T, further calculation can get influence degree, influenced degree, centrality degree and reason degree of each element, which is shown in Table 2.

Table 2: Influence degree, centrality degree and reason degree.

factor	1	2	3	4	5	6	7	8	9	10	11	12
Effect degree	1.204	0.331	0.405	1.024	0.276	0.654	0.986	0.899	1.094	0.890	0.276	0.378
centrality degree	1.454	1.081	0.405	1.474	1.297	1.204	0.986	2.200	1.344	2.696	0.837	1.855
reason degree	0.954	-0.419	0.405	0.574	-0.746	0.104	0.986	-0.402	0.844	-0.915	-0.286	-1.098

3.3 Analysis of results

As can be seen from Table 2, factors with the greatest influence degree are grid-connected technology, technology maturity and cooperation management. These factors are fundamental problems for (DES)'s development. Only when grid-connected technology is solved and cooperation management is standardized can (DES) enter market successfully. Of course, technology maturity is the basic existence condition.

Factors with the greatest centrality degree are social recognition, laws and regulations and production cost. These factors play a very important role in (DES)'s development. When (DES) is recognized by society it will get large-scale development, otherwise there are only a number of demonstration projects. The long-term development of (DES) depends on its legalized status in the form of law and favorable production cost.

Factors with the greatest reason degree are electricity regulation, grid-connected technology and technology maturity, which are reason factors. They affect (DES)'s development fundamentally and have greater effect on other factors.

The above results indicate the relative importance and the different role of various factors in the horizontal direction. In order to identify the relationship of factors and propose targeted measures, a hierarchical order is sorted vertically with ISM method.

4 Hierarchical model of factors based on ISM method

Interpretative Structural Modelling (ISM) method describes the relationship among various factors by multi-level hierarchical structure and makes the criss-crossing relationship clear. In order to build Interpretative Structural Mode, adjacency matrix composed of the factors is calculated to get reachable matrix and hierarchical division.

4.1 Reachable matrix

Adjacency matrix is established according to Table 1 and represented with matrix A. Reachable matrix is obtained by boolean operation for adjacency matrix, which presents all influence relationship among various factors. Reachable

matrix is represented by Eq.(2).

$$M = (A+I)^6 = \begin{bmatrix} 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}, \tag{2}$$

where matrix element 1 indicates that the row factor has a direct or indirect impact on the column factor (including self-related relation of factors), otherwise matrix element is 0.

4.2 Division of factor level

In reachable matrix M, factors that can not reach the other factors besides themselves are known as the highest factors. Find all the highest factors and divide them into a set. It is seen as the first-class factors set. Then remove the row and the column corresponding to the highest factors from reachable matrix and continue to look for the new set of the highest factors in the rest of the matrix. The rest may be deduced by analogy. All sets of the highest factors are found and divided into three levels with regard to the 12 factors in the matrix. The division is represented by Eq.(3).

$$L1 = \{f_2, f_5, f_6, f_8, f_{10}, f_{11}, f_{12}\}, \;\; L2 = \{f_4, f_7\} L3 = \{f_1 f_3, f_9\} \tag{3}$$

where f_i indicates factor i.

According to the levels of division, the factors are sorted and the matrix becomes reduced reachable matrix by removing the strongly connected domain. The reduced reachable matrix is represented by Eq.(4).

$$M^* = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

According to the reduced reachable matrix, multi-level hierarchical structure is established for the influencing factors of (DES)'s development that is shown in Figure 2.

4.3 Analysis of results

The bottom factors are the most basic and objective factors which can be seen as the deepest reasons. Technology maturity is the prerequisite for (DES)'s development. Mature technology and reduced restructure cost make it easier to reach grid-connected protocol, and thus also lower the market threshold for (DES).

The middle lever is a soft support. Strengthening the cooperation between power grid companies and (DES) contributes to provide a favorable living environment for (DES)'s development. If electricity regulation focuses more on environmental benefits, service quality and supply security, (DES)'s development will be more popular.

Surface factors have the most direct impact on (DES)'s development. Some measures of government will help to break market monopoly and encourage (DES)'s development, such as simplifying permit approval procedures, providing financial subsidies or tax relief, regulating grid-connected standards in form of laws and regulations, legalizing (DES) in law, etc. Production cost, financing channel, social acceptance are the existence foundation of (DES), whose importance for (DES) is self-evident. But these factors are also affected by many other factors and can only be improved gradually.

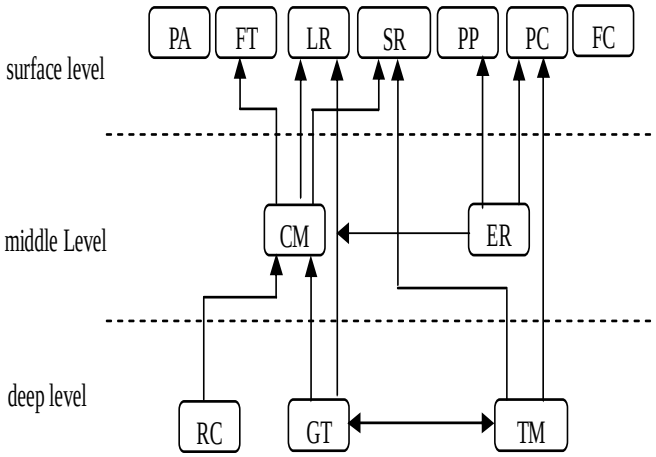


Figure 2: Multi-level hierarchical structure of factors.

5 Conclusion

In this paper, DEMATEL and ISM methods are applied to study the influence factors of (DES). The conclusion presents not only the most important factors and the fundamental factors but also the relationship of all the factors. The most influential factors are grid-connected technology and technology maturity. They are the most fundamental problem for (DES)'s development and affect the other factors. So technology should be developed firstly. Social recognition, laws and regulations and production cost have the most direct impact on (DES)'s development. They are the most realistic problems for (DES)'s further development.

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