Research on Identification of Influencing Factors and Mechanism Analysis Based on DEMATEL-ISM Theory

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Abstract. Against the backdrop of the new power changes, with the expansion of the investment scale, the power supply profit margin and operational pressure are also increasing. Therefore, in making investment decisions, power grid companies should not only consider factors such as power demand, power supply capacity, and power supply reliability but also conduct a thorough analysis of their actual investment requirements to formulate scientifically sound and rational investment strategies. To this end, considering the specific characteristics of investment activities in power grid enterprises, a methodology based on distributed theory is proposed for identifying influencing factors and analyzing the underlying mechanisms of power grid investment demand. This approach serves as a reference for power grid enterprises to enhance the quality of investment decision-making and optimize the efficiency of investment fund utilization.

Keywords: power grid investment demand, DEMATEL-ISM theory, influencing factors, and analysis technology

1 Introduction

Power grid projects are inherently characterized by extended construction periods, involvement of multiple stakeholders, and substantial capital investment. Consequently, the factors influencing the total investment in power grid projects are multifaceted and complex. Hence, scientifically and reasonably identifying and in - depth analyzing various influencing factors can further improve the investment efficiency of power grid enterprises.

In recent years, scholars have made significant advancements in analyzing the factors influencing power grid investment. However, a critical review of the existing literature reveals notable gaps, underscoring the necessity of this study. Reference [1] examines the influencing factors of urban power grid asset scale from three dimensions: investment demand, investment environment, and investment capacity. It establishes a systematic framework of influencing factors and employs correlation coefficient analysis to assess the degree and direction of their impact on asset scale.Reference

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[2] investigates multiple indicators influencing power grid development from three dimensions: social, economic, and environmental performance. Utilizing extensive power data and employing grey correlation analysis, the study identifies relationships between these indicators and power grid investment, ultimately determining key indicators. This approach enhances the effectiveness and accuracy of forecasting power grid investment demand and aids in optimizing the framework of the power grid investment indicator system. Reference [3] synthesizes existing research on the factors influencing power grid investment, primarily focusing on the interplay between power grid investment and economic development.

This research provides valuable references for power grid enterprises to accurately determine investment scales and strategically formulate investment plans.Literature [4] takes the distribution network as the research object and uses qualitative analysis methods to analyze the main factors affecting its investment demand. Literature [5] comprehensively sorts out the set of factors affecting the formation of the total investment in power grid projects and extracts 12 main influencing factors through principal component analysis. Based on their inherent characteristics, the primary influencing factors can be categorized into two groups: uncontrollable factors and management-related factors.and we propose that management factors should be the focus of investment management and control, so as to provide reference for precision investment management and control of power grid engineering.

In summary, this study systematically combines the semi - dataset - ism method with scenario - based simulation to address the limitations found in previous studies. Different from existing research that mainly focuses on correlation analysis or subjective identification methods, this study provides a quantitative and hierarchical framework for evaluating the complex interdependencies among the influencing factors of power grid investment demand. By incorporating dynamic scenario modeling—including varying economic and load growth rates—this research effectively bridges the gap between theoretical factor analysis and practical application,and offers insights for future - oriented investment strategies. The results indicate that core factors, including power supply capacity and load distribution, significantly influence investment demand, whereas external factors, such as urbanization and economic growth, serve as fundamental driving forces. This analytical approach not only deepens the understanding of causal relationships and hierarchical structures but also confirms the practical applicability of the proposed framework through empirical validation.In conclusion, this study provides a comprehensive decision - making tool for power grid enterprises, enabling more precise investment planning and improving the efficiency of resource allocation.

2 Identification of Influencing Factors of Power Grid Investment Demand Based on Fish Bone Map

The scale of the power grid directly influences power transmission efficiency, social service capability, and resource optimization. Investment demand for power grids is determined by numerous factors, including grid scale planning, coverage definition, capacity planning (such as generation and transmission capacities), investment capability, spatial distribution, and transmission line length [6]. The development demand for the power grid scale comes from multiple levels. The first level comes from external driving factors, mainly the country's demand for social and economic development, which is divided into power supply, load demand, national economic and social development, and macro - factors; the second level comes from internal needs. According to the "Blue Book on the Development of the New Power System", the new power system has four important characteristics of safety, efficiency, cleanliness, low - carbon, flexibility, and intelligent integration, which are divided into economic, efficient, safe operation, reliable power supply, and digital intelligent transformation. Through a comprehensive review of relevant literature, the specific influencing factors have been identified, as illustrated in Fig. 1:

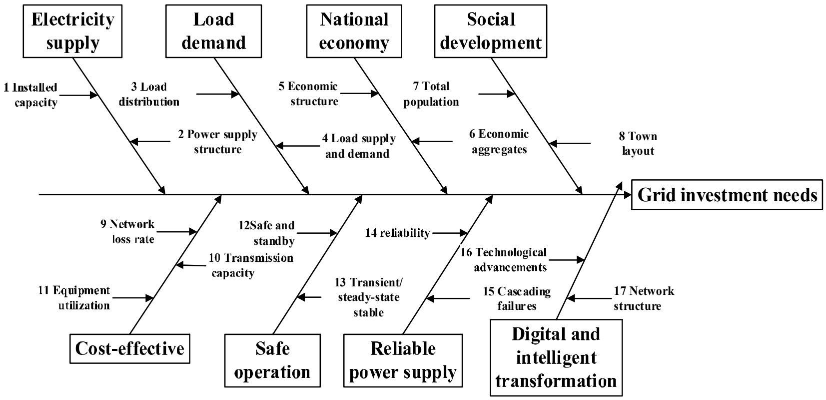

Fig. 1. Fish bone diagram

3 Impact Factor Measures Based on the DEMATEL-ISM Model

3.1 The DEMATEL-ISM Model Principle

Decision-making Trial and Evaluation Laboratory (DEMATEL) is an analytical approach employing graph theory and matrix techniques to investigate system components. By evaluating logical interrelations and direct influences among these components, DEMATEL quantifies both the relationships and their corresponding intensities [7].

Interpretive Structural Modeling (ISM) is a methodological framework designed to decompose complex systems into manageable subsystems (elements) and subsequently reconstruct a hierarchical structural model through algebraic operations. Utilizing matrix calculations, the ISM approach determines causal linkages and quantifies the strength of interactions between factors, effectively identifying critical factors and assessing their degree of influence.However, this method cannot effectively identify the hierarchical structure of factors in the system. By analyzing the direct binary correlations between subsystems (factors or elements) of the system, a multi - level directed topological graph based on Boolean algebraic operations is constructed, but the degree of influence of elements on the system cannot be determined. Therefore, by combining these two methods, the key elements in the system and their degrees of influence can be identified, and the hierarchical structure of these elements can be constructed.

In this study, the distributed network - ism method is specifically customized for power grid investment demand. By introducing a dynamic threshold to eliminate weak relationships, the key factors in complex systems can be better distinguished. In addition, we also adopted an improved expert scoring method, which reduces bias by averaging the inputs from multiple stakeholders with different professional knowledge. These adaptations ensure that the results more accurately reflect the hierarchical structure and the interdependencies between influencing factors in real scenarios.

3.2 The Calculation Steps of the DEMATEL-ISM Model

(1) Identify each element of the system. Clearly analyze the elements that make up the system and label the elements of the system as $x_1, x_2, x_3, ..., x_n$.

(2) The direct impact matrix is determined by employing an expert scoring approach, which systematically evaluates and compares the influence levels of the factors x_i on x_j, since a factor does not influence itself, the diagonal elements of the direct influence matrix are assigned a value of 0, and the direct influence matrix A is obtained by comparison.

$$A = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & 0 \end{bmatrix} \tag{1}$$

Where factor $x_{ij}(i = 1,2,...,m; j = 1,2,...,n; i \neq j)$ represents the direct influence of factor x_i on x_j. At that time, $i = j$ and $x_{ij} = 0$.

(3) Normalized Influence Matrix. The normalized influence matrix is derived by applying normalization to the original relationship matrix. Specifically, the row maximum normalization method is utilized, whereby the sum of each row in matrix A is calculated, and the largest row sum is identified. Each element in matrix A is then divided by this maximum value, resulting in the normalized influence matrix B..

$$B = \frac{x_{ij}}{\max\left(\sum_{j=1}^{n} x_{ij}\right)} \tag{2}$$

(4) The comprehensive influence matrix captures the aggregate effects of direct and indirect interactions among system factors. It is obtained by summing the direct influence matrix and the indirect influences derived from iterative multiplications of the normalized influence matrix. Mathematically, this can be expressed as follows:

$$T=\left(B+B^{2}+\cdots+B^{k}\right)=\sum_{k=1}^{\infty}B^{k}=B\left(I-B\right)^{-1} \tag{3}$$

where T represents the comprehensive influence matrix, B denotes the normalized influence matrix, I is the identity matrix, and n indicates the number of iterations until convergence.

(5) Calculate the influence degree, affected degree，centrality degree, and causality degree of each factor.

The influence degree denoted as D_i, $D_i=\sum_{j=1}^{n}x_{ij},(i=1,2,..,n)$.

The affected degree denoted as C_i, $C_i=\sum_{j=1}^{n}x_{ij},(i=1,2,..,n)$.

The centrality degree is recorded as R_i, $R_i=D_i-C_i$.

(6) The cause-and-effect diagram is constructed by plotting the centrality degree M_i on the horizontal axis (abscissa) and the causality degree R_i on the vertical axis (ordinate). This graphical representation simplifies the analysis of causal relationships among system factors. Factors located on the right side indicate higher centrality and greater importance, while their vertical positioning reveals their roles as either net influencers or net receivers within the system.

(7) Overall Impact Matrix.The overall impact matrix H is calculated by summing the comprehensive influence matrix T and the identity matrix I.

(8) Reachability Matrix.To identify clear hierarchical structures, it is necessary to eliminate weaker relationships by introducing a threshold value λ. The threshold λ is generally determined by experts or decision-makers based on practical considerations. Elements in the overall impact matrix E are processed using this threshold to obtain the reachability matrix F, defined as follows:

$$f_{ij}=\begin{cases}1, e_{ij}\geq\lambda(i,j=1,2,...,n)\\0, e_{ij}<\lambda(i,j=1,2,...,n)\end{cases} \tag{4}$$

(9) Hierarchy Division.The hierarchy is established by identifying the reachability set $R(x_i)=\{x_i\mid F_{ij}=1\}$, which includes factors corresponding to columns with values of 1 in row iii of the reachability matrix F, representing all factors reachable from factor x_i. Similarly, the antecedent set $S(x_i)=\{x_i\mid F_{ij}=1\}$ comprises factors corresponding to rows with values of 1 in column i, indicating factors that can reach factor x_i.If the condition $R(x_i)\bigcap S(x_i)=R(x_i)$ holds, then factor x_i is con-

sidered a top-level factor. Subsequently, rows and columns associated with this top-level factor are removed from the reachability matrix. This iterative procedure continues until all rows and columns have been eliminated, resulting in a clear hierarchical structure.

(10) The hierarchical ladder structure of factors can be visualized by constructing a directed topology graph, where each layer represents the sequence in which the factors are successively removed from the reachability matrix.

4 Empirical Analysis

According to figure 1 fish bone chart analysis 17 investment demand internal and external factors, invite experts on the strength of the formation factor, the directed topology graph of the ladder hierarchy structure can be visualized by categorizing relationships between system factors based on five distinct grades of influence.0：No effect；1：Small influence；2：General influence；3：Large influence；4：Very large influence.

Respectively, said the influence between the formation factor, get 17 initial direct influence matrix. In order to eliminate individual differences in expert scoring, 17 initial direct impact matrices were taken as an integer (rounded off) to construct the grid investment demand formation factor direct impact matrix, as shown in Fig 2 below.

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17
x1	0	4	3	3	1	1	3	2	0	3	0	0	0	0	0	0	0
x2	1	0	3	3	1	0	2	4	0	0	0	0	0	0	0	0	3
x3	1	3	0	3	1	1	2	3	0	3	0	0	0	0	0	0	0
x4	2	3	3	0	0	0	4	3	0	3	1	0	0	0	0	0	0
x5	0	2	2	3	0	3	3	4	0	0	0	0	0	0	0	0	0
x6	0	0	0	3	4	0	0	3	0	0	0	0	0	0	0	0	0
x7	0	0	0	0	2	2	0	4	0	0	0	0	0	0	0	0	0
x8	0	0	3	2	4	2	2	0	0	0	0	0	0	0	0	0	0
x9	1	0	0	0	0	0	0	0	0	4	3	2	1	0	0	3	0
x10	1	1	3	2	2	2	0	0	3	0	2	2	2	1	0	4	0
x11	1	0	0	0	0	0	0	0	2	3	0	0	0	2	1	3	0
x12	1	3	0	3	0	0	0	0	2	2	0	0	2	2	2	3	0
x13	2	0	0	0	0	0	0	0	0	2	2	3	0	4	2	3	0
x14	0	0	0	0	0	0	0	0	0	1	1	2	2	0	3	3	0
x15	0	0	0	0	0	0	0	0	0	0	0	3	2	3	0	3	0
x16	0	0	0	0	0	0	0	0	2	3	3	3	2	3	2	0	0
x17	0	0	3	2	3	1	0	2	0	2	0	0	0	0	0	0	0

Fig. 2. Direct influence matrix of power grid investment demand formation factor

To supplement the direct and comprehensive influence matrix analysis, we conducted scenario-based simulations of investment demand under varying economic and grid load growth rates. Table 1 presents the predicted investment demand for Fujian's power grid based on different growth scenarios, emphasizing the impact of transmission capacity increases and other influencing factors.

Table 1. Simulated Impact of Economic and Load Factors on Investment Demand

Scenario	Economic Growth (%)	Load Growth (%)	Transmission Capacity Increase (%)	Investment Demand (Billion RMB)
High Growth	6.5	8	12	150
Medium Growth	4	5.5	8	120
Low Growth	2	3	5	90
High Load Growth	3.5	10	15	180
Low Economic Growth	2.5	2	4	85

Following the analysis of the comprehensive influence matrix, further scenario-based simulations were conducted to evaluate and validate the robustness and practical applicability of the proposed framework under varying conditions. Table 1 showcases the results, highlighting the critical role of transmission capacity expansion in determining overall investment needs. Furthermore, historical data for Fujian's power grid (2013–2022) is presented in Table 2, offering insights into how economic and population growth, coupled with energy demand, shape investment trajectories. These datasets underscore the practical applicability of the DEMATEL-ISM framework in real-world contexts.

Table 2. Fujian Power Grid Historical Data (2013-2022)

Year	GDP Growth (%)	Population (Million)	Power Demand (GW)	Investment (Billion RMB)
2013	7.8	36	18.5	45
2014	7.5	36.3	19.2	46.8
2015	7.2	36.7	19.8	47.5
2016	7	37	20.5	48.3
2017	6.5	37.2	21.8	50
2018	6	37.5	22.5	52
2019	5.5	38	23.1	53.2
2020	5	38.4	23.8	54
2021	4.8	38.8	24.1	55
2022	4.5	39	24.3	55.5

The matrix presented in Table 2 was normalized using the row maximum method, resulting in the comprehensive influence matrix illustrated in Figure 3. Subsequently, the influence degree, influenced degree, centrality degree, and causality degree for each factor were computed based on this matrix.Based on these calculations, the cause-and-effect diagram is constructed and presented in Figure 4.

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17
x1	1.059	0.261	0.269	0.274	0.172	0.135	0.256	0.279	0.037	0.219	0.043	0.035	0.030	0.029	0.015	0.058	0.031
x2	0.080	1.090	0.247	0.245	0.160	0.086	0.200	0.318	0.016	0.090	0.023	0.015	0.012	0.012	0.007	0.025	0.131
x3	0.088	0.205	1.139	0.250	0.157	0.123	0.199	0.280	0.034	0.202	0.040	0.032	0.028	0.026	0.014	0.053	0.025
x4	0.127	0.211	0.251	1.144	0.127	0.094	0.274	0.289	0.040	0.215	0.079	0.036	0.031	0.032	0.017	0.063	0.025
x5	0.038	0.151	0.189	0.237	1.123	0.194	0.230	0.319	0.012	0.065	0.019	0.011	0.009	0.009	0.005	0.018	0.018
x6	0.025	0.058	0.084	0.197	0.223	1.060	0.091	0.223	0.008	0.043	0.014	0.007	0.006	0.006	0.003	0.012	0.007
x7	0.010	0.028	0.054	0.064	0.146	0.124	1.053	0.226	0.003	0.018	0.005	0.003	0.002	0.003	0.001	0.005	0.003
x8	0.030	0.073	0.198	0.180	0.238	0.148	0.174	1.144	0.010	0.057	0.016	0.009	0.008	0.008	0.004	0.016	0.009
x9	0.092	0.071	0.077	0.089	0.054	0.045	0.049	0.061	1.084	0.286	0.200	0.169	0.113	0.097	0.062	0.253	0.008
x10	0.119	0.161	0.241	0.235	0.179	0.155	0.118	0.160	0.198	1.198	0.185	0.189	0.162	0.150	0.078	0.307	0.019
x11	0.076	0.049	0.059	0.064	0.042	0.035	0.037	0.046	0.138	0.221	1.076	0.088	0.068	0.151	0.092	0.229	0.006
x12	0.108	0.208	0.116	0.231	0.074	0.054	0.094	0.119	0.145	0.231	0.096	1.112	0.160	0.180	0.148	0.258	0.025
x13	0.130	0.082	0.077	0.097	0.052	0.042	0.056	0.068	0.080	0.219	0.163	0.230	1.096	0.269	0.167	0.276	0.010
x14	0.038	0.046	0.040	0.055	0.027	0.022	0.026	0.033	0.057	0.135	0.104	0.171	0.148	1.101	0.180	0.233	0.005
x15	0.035	0.046	0.033	0.053	0.022	0.017	0.024	0.030	0.050	0.093	0.062	0.201	0.145	0.203	1.072	0.223	0.005
x16	0.061	0.072	0.070	0.089	0.049	0.040	0.043	0.056	0.162	0.262	0.209	0.235	0.173	0.235	0.164	1.183	0.009
x17	0.038	0.081	0.218	0.191	0.206	0.112	0.100	0.208	0.026	0.151	0.030	0.024	0.021	0.020	0.010	0.040	1.010

Fig. 3. Direct influence matrix of power grid investment demand formation factor

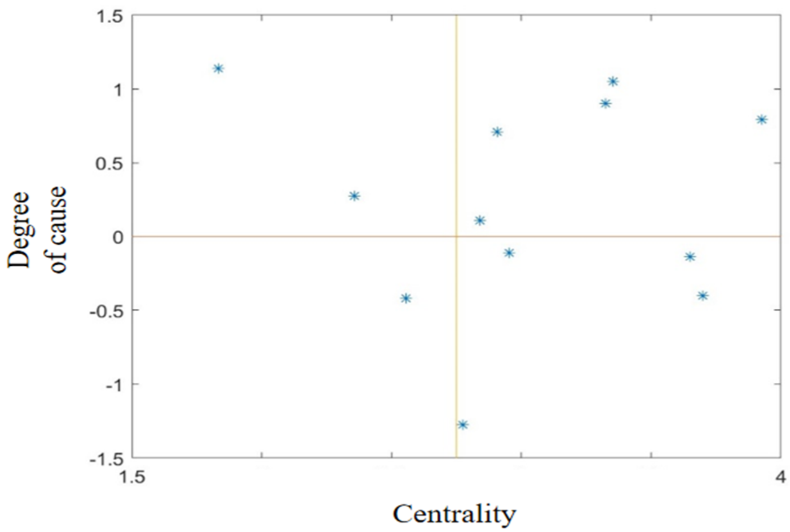

Fig. 4. Comprehensive influence matrix of factors affecting power grid investment demand

Finally, the hierarchy is divided through the accessible matrix, and the hierarchy diagram is shown in the figure 5. The factors have different levels and their correlation with other factors. Greater attention should be given to deep-seated factors and intersectional factors when conducting a comprehensive evaluation of the rationality of power grid construction scale.

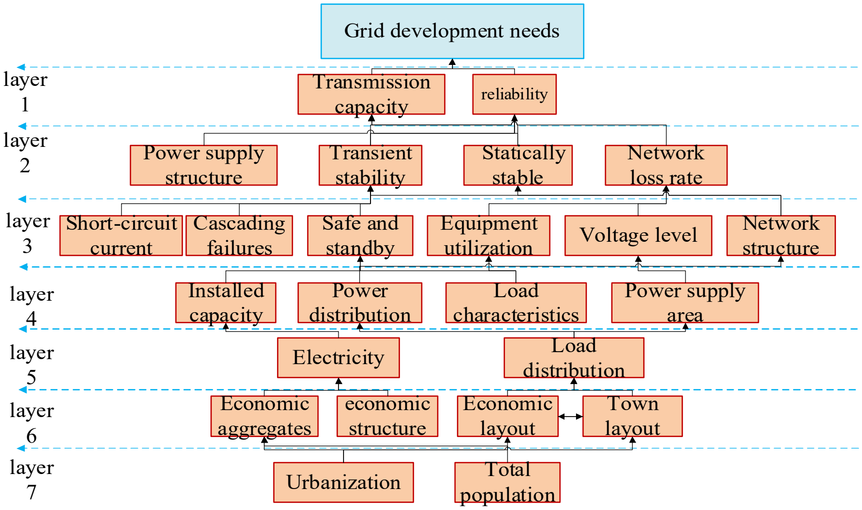

Fig. 5. Influencing factors affect the structure diagram.

Preliminary analysis indicates that fundamental factors driving power grid development demand include economic aggregate, economic structure, economic distribution, urban planning, urbanization, and population size, all of which constitute primary drivers for grid expansion. Core factors identified are power supply capacity and load distribution, as growth in power supply and evolving load distribution directly dictate development needs. Direct influencing factors comprise transmission capacity and reliability. These conclusions align closely with the empirical realities observed in power grid development.

5 Conclusion

In conclusion, this study integrates the DEMATEL-ISM framework with scenario-based simulations to develop a comprehensive methodology for identifying and analyzing the influencing factors of power grid investment demand. By combining hierarchical structural analysis with practical simulation data, the research bridges theoretical insights and real-world applications, offering a robust tool for decision-making. The findings emphasize that critical factors, such as power supply capacity, load distribution, and transmission reliability, must be prioritized to meet the growing and dynamic demands of power grid infrastructure. Moreover, external factors, including economic growth, urbanization, and population trends, serve as foundational drivers for long-term investment strategies.

From a practical perspective, the proposed framework provides actionable guidance for power grid enterprises in improving their investment decision-making processes. Specifically, the results can be directly integrated into budgeting systems to optimize resource allocation, ensure sustainable grid development, and enhance financial efficiency. By identifying high-priority factors and quantifying their impacts, the methodology supports more precise investment planning, reduces operational risks, and aligns investment strategies with broader economic and societal goals. This approach not only enhances the scientific basis for investment decision-making but also delivers practical solutions to pressing challenges in power grid management.

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