Study on Benchmarking Evaluation System for Technological Innovation of Power Grid Enterprises

Yan Chang1,a,*, Weixuan Meng
1State Grid Energy Research Institute, CHINA
*Corresponding author: emily_chang@126.com,bCdream46@163.com,c17303166@qq.com

Abstract: China attaches great importance to corporate scientific and technological innovation, and technological innovation has become a powerful driving force for continuous promotion of corporate scientific development. According to the new requirements of the 19th National Congress of the Communist Party of China on the reform and development of central enterprises and the high-quality economic development of the Fourth Plenary Session of the 19th Central Committee, the company's scientific and technological innovation index evaluation was carried out. Based on the theoretical research, evaluation methods and enterprise management practices of world-class enterprises, this article establishes an effective mechanism to guide the technological innovation of power grid enterprises and provides a scientific decision-making basis for technological innovation of power grid enterprises.

1. Introduction
The Fourth Plenary Session of the Nineteenth Central Committee made new arrangements for improving the technological innovation system and other aspects, and emphasized "to improve the scientific and technological management system and policy system in line with the laws of scientific research, improve the scientific and technological evaluation system, and improve the scientific and technological ethics governance system. At the same time, the State-owned Assets Supervision and Administration Commission (SASAC) also proposed the requirements of "forming a group of leading enterprises in international resource allocation, leading enterprises in global industry technology development, and leading enterprises with a say and influence in global industry development". The main purpose of carrying out scientific and technological innovation evaluation is to promote the construction of scientific and technological innovation system by central enterprises through evaluation work, and provide strong support for the construction of world-class enterprises.

2. Theoretical basis of enterprise science and technology innovation index
There are many research on the technology innovation index, most of which are based on countries, regions, and enterprises to evaluate their science and technology innovation activities. Typical technology innovation indexes include the EU Innovation Scoreboard, Global Innovation Index, Silicon Valley Index, National Innovation Index, and Zhongguancun Index. In contrast, there is a lack of research on the technological innovation index at the micro level of enterprises and other companies. In addition to the commonly used "EU industry R&D investment scoreboard", some scholars have also carried out research on the construction of and technological innovation indexes around micro entities such as companies or industries. For example, Cui Jindong and others (2019) established an indicator system for the innovation capability of power supply companies in China and South Korea using AHP
and fuzzy comprehensive evaluation methods. From different perspectives, Liang Xiaojie and Wang Bing (2017) established an evaluation index system based on patent information for domestic and foreign steel industry technology innovation capabilities, and selected Baogang, Angang, Harbin Institute of Technology and other research objects to practice the evaluation index system. The technology SME Innovation Index proposed by Xie Yanzhao and Hao Shouyi's (2015) is an evaluation of China's technology SMEs' comprehensive innovation capabilities. Ma Qin (2018) proposed that the manufacturing enterprise technology innovation index is a comprehensive index based on the comparative evaluation of the base period index to measure the manufacturing enterprise's technological innovation capability and the effectiveness of the technological innovation system.

Based on the domestic and foreign research on the scientific and technological innovation index, it can be concluded that the scientific and technological innovation index is an objective evaluation result of the designated countries, regions, enterprises and other subjects at a certain stage of scientific and technological innovation capabilities, systems, and overall activities. Through the research of technology innovation index, each innovation subject can more accurately grasp the benefits and deficiencies of its own science and technology innovation activities at this stage, which is more conducive to future development.

The enterprise science and technology innovation index currently has several definitions such as capacity theory, resource theory, result theory, innovation chain theory and industry chain theory. On the whole, scholars / experts / institutions have put together the technological innovation index and the evaluation of technological innovation. There are currently five views on the definition of the concept of enterprise technology innovation index / evaluation: First, from the perspective of capability, it is believed that the enterprise's technological innovation index is a centralized reflection of technological innovation capability. It is an enterprise's ability to effectively use various resources of scientific and technological innovation under the certain technical and economic conditions, with the purpose of improving the quality of the enterprise and enhancing the competitiveness of the enterprise as the starting point and destination. It is a combination of a series of sub-abilities. The second is from the perspective of results. Thomson Reuters' global 100 leading innovators evaluation is a set of evaluation systems constructed from the perspective of innovation output and influence, which is based on patent data and analysis, focusing on the total number of patents, patent grant rate, globalization, and citation influence. The third is from the perspective of the innovation chain, that the enterprise technology innovation index is a concentrated reflection of the efficiency of the entire system of activities such as the input of resources, innovation management process, and output of innovation achievements by enterprises, schools, scientific research institutions, or natural persons in technological innovation activities. Fifth, from the perspective of technological ecology, the technological innovation index is a concentrated expression of the efficiency of innovation activities in the entire relevant industry where the enterprise is located.

3. Benchmark enterprise selection and index database construction

The research team selected 10 benchmarking companies for a comprehensive review, and built a three-dimensional index database around the internationally-used technology innovation index through the investigation and index data collection of the first-class enterprise technology innovation index evaluation system. Finally, the scientific and technological innovation data were fully displayed through 4 dimensions, 10 benchmarks, 16 key indicators, a 5-year statistical interval, and 500 data.

4 dimensions: including national innovation foundation, innovation management, innovation achievements, and innovation effectiveness. Under each dimension. There are corresponding secondary evaluation indicators of different scopes.
10 benchmarks: Based on the 2018 Fortune Global 500 data and corporate social responsibility report data, we selected the top 10 foreign companies in the world's top 500 in terms of operating income other than the State Grid Corporation to conduct benchmarking analysis. In order: ENEL Group, Uniper, Electricite De France, State Power Investment Corporation Limited, Engie, China Southern Power Grid Company Limited, Tokyo Electric Power Company, Korea Electric Power Corporation, RWE Group, E.On Group.

16 key indicators: internationally-used key indicators in the "world-class power grid" indicator system.

5-year statistical interval: A total of 5 years of data mining in each country from 2014 to 2018.

500 pieces of data: The entire international key indicator database contains 500 pieces of data, which presents indicators and country information from multiple angles and levels, involving more than 800 specific dimension information and indicator data.

Table 1 Basic situation of power companies listed in 2018

| Number | Rank | Company                                      | Operating Income (million dollars) | Profit (million dollars) | Assets (million dollars) | Shareholders' equity (million dollars) | Nation            | Employee (ten thousand) |
|--------|------|----------------------------------------------|----------------------------------|-------------------------|-------------------------|---------------------------------------|------------------|------------------------|
| 1      | 2    | State Grid                                   | 348903                           | 9533                    | 585278                  | 239743                                | China            | 91.4                   |
| 2      | 83   | ENEL Group                                   | 84134                            | 4260                    | 186889                  | 41781                                 | Italy            | 6.3                    |
| 3      | 88   | Uniper                                       | 81428                            | -740                    | 51826                   | 14586                                 | Germany          | 1.3                    |
| 4      | 94   | Electricite De France                        | 78490                            | 3577                    | 337118                  | 49660                                 | France           | 15.1                   |
| 5      | 101  | State Power Investment Corporation Limited   | 75522                            | 2495                    | 274441                  | 61289                                 | China            | 31.3                   |
| 6      | 104  | Engie Group                                  | 75279                            | 1604                    | 180514                  | 43995                                 | France           | 15.5                   |
| 7      | 110  | China Southern Power Grid Company Limited    | 72787                            | 1938                    | 113886                  | 43896                                 | China            | 30.0                   |
| 8      | 186  | Tokyo Electric Power Company                 | 52809                            | 2871                    | 118422                  | 24868                                 | Japan            | 4.2                    |
| 9      | 188  | Korea Electric Power Corporation             | 52492                            | 1149                    | 169833                  | 66967                                 | South Korea      | 4.5                    |
| 10     | 214  | RWE Group                                    | 47832                            | 2189                    | 82924                   | 9245                                  | Germany          | 6.0                    |
| 11     | 254  | E.On Group                                   | 42795                            | 4424                    | 67183                   | 4812                                  | Germany          | 4.3                    |

Source: According to the relevant information on the "Fortune" website, it is listed in the order of 2018 ranking.

4. Selected analytical methods and tools

At present, the research on the quantitative evaluation of the "first-class level" of scientific and technological innovation indicators is still blank in the world. Throughout other fields, the research scope and achievements of applied data classification mainly include the following two aspects. On the one hand, cluster analysis theory is the focus of current data classification research and application. The optimal segmentation method proposed by Fisher in 1958, as one of the classification methods of ordered sequence, is now widely used in the fields of machine tool thermal critical point analysis, ocean thermocline boundary analysis, grassland fire risk warning threshold analysis, river basin flood season stages, enterprise credit rating, etc. In 1967, MacQueen proposed the K-means clustering algorithm. He summarized the research results of Cox, Fisher, Sebestyen, etc., and proposed the
detailed steps of the K-mean clustering algorithm, which was proved by mathematical methods. In 1975, Hartigan systematically discussed clustering algorithms in his monograph Clustering Algorithms. On the other hand, for the dimensionless processing of data grading indicators, many scholars have proposed different methods. In practical applications, quantitative indicators are usually divided into five types: benefit type, cost type, fixed type, interval type and deviation type.

For the indicators that can be obtained from the international sample data, the numerical analysis method is used in conjunction with the international sample database to determine the first-class level of the indicator; for some indicators that cannot be compared with the international sample due to differences in statistical habits and evaluation methods, the relevant professional departments choose domestic or equivalent regions as the first-class level range of such indicators.

Based on the theoretical study of data classification, this study mainly used five-point method, optimal segmentation method and k-means clustering analysis method for quantitative evaluation, and finally took the average value of the three methods as the recommended "first-class level" interval.

5. Quantitative analysis results
Based on the data of the most recent years of the indicator samples selected by the indicator database, the quintile method, the optimal segmentation method, and the K-means clustering method are used to perform the quantitative calculation of the first-class horizontal interval of key indicators. On this basis, the average values of the three methods were taken as the international first-class level interval of each key indicator. Based on the constructed index database, the first-class level interval quantitative analysis tools of indicators are used to calculate the first-class level interval of scientific and technological innovation index indicators. The detailed results are shown in the following table.

Table 2: index interval distribution of science and technology innovation of international first-class enterprises

| Dimensions                  | Indicators                                                                 | Quintile       | Optimal segmentation | K-means cluster analysis | Recommended First Class |
|-----------------------------|-----------------------------------------------------------------------------|----------------|-----------------------|--------------------------|------------------------|
| Innovation foundation       | Total investment in R&D (100 million yuan)                                  | 40-85          | 42-88                 | 35-88                    | 39-87                  |
|                             | R&D investment intensity (%)                                                | 2%-5.6%        | 2.2%-5.3%             | 2.4%-5.7%                | 2.2%-5.5%              |
|                             | Knowledge of basic scientific research / key technologies in the industry  | 83-100         | 85-100                | 87-100                   | 85-100                 |
|                             | Total investment of R&D personnel (Number of people)                        | 2520-4070      | 2535-4080             | 2544-4081                | 2533-4077              |
|                             | Proportion of R&D personnel with master degree or above (%)                 | 38%-63%        | 40%-66%               | 42%-66%                  | 40%-65%                |
|                             | R&D personnel input intensity (%)                                          | 2.35%-4.9%     | 2.3%-5%               | 2.41%-5.1%               | 2.38%-5%               |
| Innovation management      | Strategic Positioning                                                       | 84-100         | 84-100                | 87-100                   | 85-100                 |
|                             | Innovative management system fluency                                       | 82-100         | 83-100                | 84-100                   | 83-100                 |
|                             | Innovation industry chain layout                                           | 79-100         | 80-100                | 81-100                   | 80-100                 |
|                             | Academic institutions or enterprises jointly build R&D institutions / platforms (Quantity) | 308-680 | 312-685 | 313-687 | 311-684 |
| Innovation achievement     | Number of international standards (Quantity)                                | 58-85          | 60-89                 | 62-96                    | 60-90                  |
|                             | Number of international patents (Quantity)                                  | 57-73          | 55-70                 | 62-77                    | 58-75                  |
|                             | Number of awards above national awards                                     | 38-55          | 40-59                 | 42-60                    | 40-58                  |
| Innovation and effectiveness| Scientific and technological                                               | 35-52          | 33-54                 | 34-53                    | 34-53                  |
6. Research and judgment of technological innovation and development direction of power grid enterprises

Comprehensive study on the evaluation system of scientific and technological innovation of world-class enterprises, 16 goal-oriented key indicators that are commonly used and of high concern in the world are selected, total R&D investment, R&D investment intensity, mastery of basic scientific research / key technologies in the industry, R&D Total number of staff input, proportion of R&D personnel with master's degree or above, strength of R&D personnel input, strategic positioning, fluency of innovation management system, layout of innovation industry chain, number of R&D institutions / platforms jointly established by academic institutions or enterprises, number of international standards, number of international patents , the number of national awards and above, the income from the transfer of scientific and technological achievements (100 million RMB ), the consumption of clean energy emission reductions, and the evaluation of related industries to promote the "international first-class enterprise technology innovation".

First, the indicators are divided into positive indicators, negative indicators and moderate indicators according to their own characteristics. Project team use the quintile method based on normal distribution, the optimal segmentation method and the K-Means method to classify and quantify the key indicator data series of the international power grid, and then quantify it accurately; Then, through the international first level grid key indicators of quantitative evaluation software "to quantify key indicators respectively with three methods for quantitative assessment, which shows that the quintile method is suitable for calculating indicators with scattered data distribution, and it works better when dealing with reverse indicators, but sometimes there will be an erroneous result of no enterprise in the first-class interval. The optimal segmentation method is suitable for calculating data-intensive indicators, and the effect is better when dealing with positive indicators. The K-Means algorithm is suitable for calculating moderate indicators; finally, combined The advantages and disadvantages of the three methods, according to the distribution characteristics of different enterprise index data and operating environment characteristics, give the recommended first-class interval for each key indicator, and select the average of the three methods as the recommended "first-class level" interval.

Table 3 diagnosis and analysis details of the current situation of key indicators of scientific and technological innovation of the company

| The serial number | Key indicator name | Unit | Current level of indicators (2018) | Current data sources | Diagnostic result |
|------------------|--------------------|------|-----------------------------------|----------------------|------------------|
| 1 | Total investment in R&D (RMB 100 million) | 100 million yuan | 79.88 | Data provided by the Ministry of Science and Technology | International leader |
| 2 | R&D investment intensity (%) | % | 0.31% | Data provided by the Ministry of Finance and the Ministry of Science and Technology, and the ministry of science and technology made centralized statistics | There is a gap |
| 3 | Knowledge of basic scientific research / key technologies in the industry | \ | 65 | Statistical results of senior experts in the energy industry | There is a gap |
The serial number | Key indicator name | Unit | Current level of indicators (2018) | Current data sources | Diagnostic result
--- | --- | --- | --- | --- | ---
4 | Total investment of R&D personnel (Number of people) | Number of people | 5089 | Data provided by the Ministry of Human Resources and the Ministry of Science and Technology, and the ministry of science and technology made centralized statistics | International leader
5 | Proportion of R&D personnel with master degree or above (%) | % | 56% | Data provided by the Ministry of Human Resources and the Ministry of Science and Technology, and the ministry of science and technology made centralized statistics | International leader
6 | R&D personnel input intensity (%) | % | 1.8% | Data provided by the Ministry of Human Resources and the Ministry of Science and Technology, and the ministry of science and technology made centralized statistics | There is a gap
7 | Strategic Positioning | | 75 | Statistical results of senior experts in the energy industry | There is a gap
8 | Innovative management system fluency | | 70 | Statistical results of senior experts in the energy industry | There is a gap
9 | Innovation industry chain layout | | 70 | Statistical results of senior experts in the energy industry | There is a gap
10 | Academic institutions or enterprises jointly build R&D institutions / platforms (Quantity) | Quantity | 88 | Data provided by the Ministry of Science and Technology | There is a gap
11 | Number of international standards (Quantity) | Quantity | 41 | Data provided by the Ministry of Science and Technology | There is a gap
12 | Number of international patents (Quantity) | Quantity | 62 | Data provided by the Ministry of Science and Technology | International leader
13 | Number of awards above national awards | Quantity | 33 | Data provided by the Ministry of Science and Technology | There is a gap
14 | Scientific and technological achievements transfer income (RMB 100 million) | 100 million yuan | 2.3 | Data provided by the Ministry of Finance and the Ministry of Science and Technology, and the ministry of science and technology made centralized statistics | There is a gap
15 | Consumption of clean energy emission reduction (Ten thousand tons) | Tons/year | 114000 | | International leader
16 | Leading role in related industries | | 65 | Statistical results of senior experts in the energy industry | There is a gap

7. Conclusion
Of the 16 key indicators that are internationally comparable, "The total investment of R & D Funds, the total investment of R & D personnel, the proportion of R & D personnel with master degree or above, the number of international patents, the amount of clean energy emission reduction absorbed and the number of national awards obtained" are in the first-class level in the world "R & D EXPENDITURE INTENSITY, strategic positioning, innovation management system fluency, innovation industry chain layout, international standard quantity, academic institutions or enterprises to build R & D Institutions / Platforms" and other six indicators are less than the international first-class level, continue to consolidate and upgrade will be able to reach the international advanced level; There is still a big gap between the FOUR INDICATORS OF "R & D personnel input intensity, mastery of basic scientific research / key technologies in the industry, income from transfer of scientific and technological achievements, and leading role in related industries" and the international first-class level, measures are also needed to further narrow the gap with world-class standards.

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1 Yin Zhijun, Lang Feiyuan, Chen Liwen. Comparative Research on Evaluation Methods of Enterprise's Science and Technology Innovation Capability [J]. Science and Technology Management Research, 2009 (4): 1-4.

2 First, Uniper started independent operation on January 1, 2016; second, some indicators are not available for every company due to the difficulty of obtaining data.

References
[1] Tuggle, C. S., Schnatterly, K. & Johnson, R. A. Attention patterns in the boardroom: how board composition and processes affect discussion of entrepreneurial issues [J]. Academy of Management Journal, 2010, 53 (3): 550-571.
[2] Tyler, B. B., Steensma, H. K. Evaluating technological collaborative opportunities: a cognitive modelling perspective [J]. Strategic Management Journal, 1995, 16 (2): 43-70.
[3] Uyarra E. What is Evolutionary about ‘Regional Systems of Innovation’? Implications for Regional Policy [J]. Journal of Evolutionary Economics, 2010, 20 (5): 115-137.
[4] VonZedtwitz, Maximilian, Ikeda, Tadashi; Gong, Li; Carpenter, Richard; Hamalainen, Seppo. Managing Foreign R&D in China[J].Research technology management, 2007, 33 (3): 19-27.