Research on Smart Grid Value-added Services Evaluation Based on Enterprise Ecology Method

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Abstract. Smart grid value-added service is one of the important forms of smart grid comprehensive benefits. It is also the inevitable outcome of certain stage of smart grid development and diversified demands. To ensure the sustainable and healthy development of smart grid value-added services, it is urgent to construct a smart grid value-added service evaluation system. In this paper, the smart grid value added service evaluation is studied. The complete procedure, including index system construction, comprehensive evaluation method selection and evaluation results analysis, are established. The index system is built based on the Enterprise Ecology theory and evaluated with the DAHP-TOPSIS method. Three dimensions, including external environment, enterprise profitability and social contribution, are considered and evaluated, which assists to provide several important references for the planning and the implementation of smart grid value-added projects. The case study verifies the scientific nature and accuracy of the index system and method proposed in this paper.

Introduction
Commissioning of a large number of smart grid projects lays a solid supporting and basis for deeply development of smart grid construction, the projects which have been built bring many potential value-added service forms by creating comprehensive benefits. However, there are a series of problems need to be solved of smart grid value-added service implementation, including market prospect, degree of competition, input-output benefit and market risk, etc.

With development of smart grid technology, the categories of its value-added service will become more abundant, and its covering range will be wider. When some value-added services develop to a certain scale, it may become one part of power grid’s main business, and some novel value-added service may deviate from the existing services.

Through systematic analysis on smart grid value-added service’s concept and its characteristics, this paper puts forward a comprehensive evaluation index system based on Enterprise Ecology Theory (EET), and conducts calculation by using DAHP-TOPSIS method. Ultimately, a complete and scientific evaluation system of smart grid value-added service is established, which provides theory and method support to centralize advantage resources, formulate scientific planning, and orderly promote smart grid value-added services for power grid enterprise. For the rest part of this paper, the theory basis of evaluation index system and the establishment process of the system are described in detail. The method applied to conduct evaluation process is described. Then the case study and valuable results are carried out. The research conclusions are made finally.

Establishment of Evaluation Index System
Construction and operation of smart grid not only involves electricity industry, but also needs support and coordination of the upstream and downstream firms in the industry chain. Based on this, this paper introduces the EET, and applies this theory to establish evaluation index system of smart grid value-added services. It is composed of two parts, namely biotic components and abiotic components.
Biotic components refer to the industry chain, including investor, supplier, homogeneous enterprises, market intermediates and consumers. Besides, the abiotic components refer to the external environment, namely the nature ecology environment and social ecology environment. The idea of enterprise ecology is sourced from biological relationship as well as the relationship between biology and environment. Organisms need a healthy external ecological environment and harmonious relationship between individuals for living. Based on this, EET is aimed at studying the relationship between enterprises and with the external environment, then exploring the impact of environment on enterprise, and the reaction of enterprise to environmental.

The study of EET is still at an initial stage. Currently, the evaluation model, method and index system of enterprise performance based on EET are not mature, but EET [2-4] has received considerable attention of many scholars, and has been explored in different industries. Combining smart grid development characteristics of China, this paper establish smart grid value-added service evaluation index system. From the angle of interaction and coordinated development between enterprise and environment, smart grid value-added service evaluation index system is constructed from three aspects, including outside circumstance, profitability and social contribution of carrying out business. And the evaluation structure is composed of target layer, rule layer, sub-rule layer and basic layer, as shown in Fig. 1.

Figure 1. Smart grid value-added service evaluation index system.
Target layer: The general target of smart grid value-added service evaluation index system is to evaluate development and leading level of smart grid value-added service in its enterprise ecology system. That is, in the operation period, whether the smart grid value-added service could exert its function in the whole system, and boost development of the whole system besides realizing its own development.

(1) Rule layer: Rule layer is the concrete reflection of the target layer, and it could be divided into three aspects, namely external environment, corporation profitability, and social contribution. Further, external environment is divided into two sub-rule layers, including market prospect and macro policy. Corporation profitability is divided into three sub-rule layers, covering project input and output and technology support. Social contribution is divided into three sub-rule layers, incorporating impacts on social economy, ecology environment and public environment.

(2) Sub-rule layer: The indexes of sub-rule layer are formed from basic factors, which provides basic frame for collecting information, and reflects certain basic information that affect smart grid value-added service.

(3)Basic layer: Basic layer is at the bottom of comprehensive evaluation index system, and is formed by basic indexes that could represent sub-rule layer.

**Evaluation Method**

Considering the difficulty of obtaining historical operation data, meanwhile some indicators are difficult to quantify, this paper applies the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method, combining Analytic Hierarchy Process (AHP) and Delphi methods to overcome evaluation difficulty and implement evaluation efficiency. The evaluation method this paper proposed is a combined evaluation model. The Delphi and AHP [5-7] method is mainly used to weight the indexes, and turn the qualitative indexes into quantitative indexes. The TOPSIS [8-9] is applied to calculate the final evaluation results.

The procedure is as follows:

1. Establishing the index system of smart grid value-added service commercial mode based on EET.
2. Obtaining the raw data $x_{ij}$ by data collection and analysis, and determining the value of qualitative indexes by Delphi method.
3. Determination the weight of each index.

   1) Establishment of judgment matrix. Judgment matrix represents the importance comparison between elements in hierarchy model. Judgment matrix is set as

   \[
   A = \begin{bmatrix}
   a_{11} & a_{12} & \cdots & a_{1n} \\
   a_{21} & a_{22} & \cdots & a_{2n} \\
   \vdots & \vdots & \ddots & \vdots \\
   a_{m1} & a_{m2} & \cdots & a_{mn}
   \end{bmatrix}
   \]

   \[a_{ij}\] represents the importance value between $A_i$ and $A_j$. The value is confirmed by 1-9 scoring standard.

   2) Judgment matrix consistency test.

   \[CI = (\lambda_{\text{max}} - m) / (m - 1)\]

   Where, $m$ is the order of the matrix; CR is the consistency coefficient,

   \[CR = CI / RI\]

   When $CI < 0.10$, the judgment matrix has satisfactory consistency, otherwise the judgment matrix need to be adjusted until it has a satisfactory consistency.

   When satisfying the consistency check, judgment matrix eigenvector corresponding to the largest eigen value is the weight.
w = \{w_1, w_2, \ldots, w_j\} \tag{4}

(4) Processing the raw data. Dimensionless treatment the raw data according to the formula

\[ x_i^* = x_i / \sum x_i \tag{5} \]

(5) Evaluation.

Calculating the evaluation results by TOPSIS method. Using weighted distance formula

\[ y_i = \sum w_j (x_{ij} - x^*)^2, y_i = \sum w_j (x_{ij} - x^-)^2 \tag{6} \]

Where, \( y_i \) is the distance, \( x^* \) is the ideal point, it has positive ideal point \( x^+ \) and negative ideal point \( x^- \). Then, this paper uses the Queuing indication value to exhibit the distance to negative ideal point.

Queuing indication value:

\[ c_i = y^-_i / (y^-_i + y^+_i) \tag{7} \]

TOPSIS method uses relative adjacent degree as the queuing indication value.

Relative adjacent degree:

\[ d_i = \langle \Delta u_i, \Delta u \rangle / \| \Delta u \|^2 \tag{8} \]

where,

\[ \Delta u_i = u_i - u^- \quad \Delta u = u^+ - u^- \tag{9} \]

\( \langle \Delta u_i, \Delta u \rangle \) is the inner product of \( \Delta u_i \) and \( \Delta u \)

\[ \| \Delta u \| = \left\{ \sum_{j=1}^{n} (u^+_j - u^-_j)^2 \right\}^{1/2} \tag{10} \]

Case Study and Results

Based on the smart grid value-added service evaluation index system proposed by this paper, and via using DAHP-TOPSIS method, three typical cases are analyzed including power fiber to the home (PFTTH), smart home/community and electric vehicle trial project.

The evaluation results are shown in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>PFTTH</th>
<th>Smart home / community</th>
<th>Electric vehicle charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result</td>
<td>0.842</td>
<td>0.427</td>
<td>0.882</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

According to the rank of evaluation results, the first place is electric vehicle charging. There are several reasons. Firstly, the external environment becomes increasingly mature, and the market prospects turns to be better. The government also has introduced plentiful supportive policies. Secondly, with the technical research and application, electric vehicle technology is improved rapidly, more new charging equipments are produced and various standards of electric vehicles are established. Thirdly, the development of electric vehicles can achieve comprehensive social benefits, including leading industry chain development, pollution reduction, energy conservation and environment protection. Also it can improve the convenience and economy of the lives of residents.

The evaluation results of the three dimensions of rule layers, including external environment, corporate profitability and social contribution, are listed in Tab. 2 and Fig. 1.
On the external environment, electric vehicle charging and PFTTH have better evaluation results, which reveals that both the two business models have good market prospects and policy support. On the corporate profitability, the result of PFTTH is the best, followed by the electric vehicle charging and smart home/community. PFTTH has now established a set of practical cooperation and service modes, the benefit prospect is bright. Since the infrastructure investment of electric vehicle charging is huge, this service cannot achieve profit in short time. Besides, smart home/community is still in test phase so that its efficiency is limited. On the social contribution, electric vehicle charging is the best. The reason lies in that electric vehicle is irreplaceable in promoting socio-economic development, protecting ecological environment and servicing users lives.

Table 2. Results of three dimensions of rule layer 2.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>PFTTH</th>
<th>Smart home/community</th>
<th>Electric vehicle charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>External environment</td>
<td>0.998</td>
<td>0.670</td>
<td>0.999</td>
</tr>
<tr>
<td>Corporate profitability</td>
<td>0.856</td>
<td>0.481</td>
<td>0.613</td>
</tr>
<tr>
<td>Social contribution</td>
<td>0.554</td>
<td>0.471</td>
<td>0.990</td>
</tr>
</tbody>
</table>

Summary

The sustainable and healthy development of the smart grid value added services is the requirement of the smart grid, social development and people's life. In this paper, the smart grid value-added service evaluation system is studied. The external environment, corporate profitability and social contribution of value-added services are considered, which is important for the plan, implementation of smart grid. Through analysis, the existing value-added services show diversified evaluation results. Among them, PFTTH and electric vehicle charging shows better comprehensive benefits than smart home/community. Moreover, PFTTH has more advantages on improving corporate profitability and electric vehicle charging shows more superiority on make social contribution.

The technology, policy, economic situation and external environment are rapidly changing. In order to ensure maximum benefit of developing value added services, the dynamic evaluation is necessary for adjusting the future management and development strategy.

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References


