Economic Benefit Evaluation Analysis for Distributed Energy Generation Projects Based on CRITIC-TOPSIS model

Yongqi Yang1,*, Chaoyuan Li2, Wanlei Xue1, Shuyu Kang1

1Economic and Technology Research Institute, State Grid Shandong Electric Power Company, Jinan, China
2School of Finance, Shanghai University of Finance and Economics, Shanghai, China

*Corresponding author e-mail: yangyongqincepu@163.com

Abstract. Along with the technology reform and equipment promotion, distributed energy generation has taken a great-leap-forward development and becoming more and more flexible and reliable. Nowadays, distributed energy generation has become a critical way to promote the consumption of new energy generation. This paper has established the CRITIC-TOPSIS model to evaluate the economic benefit of distributed energy generation projects. The CRITIC-TOPSIS model was put into example analysis and verified its practicability and rationality.

1. Introduction
Along with the rapid development of renewable energy generation, many researches are now focusing on the consumption of renewable energy generation. Compared with large new energy generation bases like large wind farms and PV bases, distributed energy generation is able to answer the power demand changes rapidly [1]. In addition, the remarkable technology reform has made distributed energy generation more flexible and reliable [2, 3]. Hence distributed energy generation is considered as a critical way to promote consumption of renewable energy generation nowadays.

There are several construction and business modes to carry out the distributed energy generation projects. However the optimal selection between these modes are extremely critical to the economic benefit of projects, especially when the geographical environment conditions are taken into consideration [4]. In order to solve the problems above, this paper builds economic benefit evaluation index system according to the operation features of distributed energy generation projects. Besides, we further optimizes the TOPSIS model through suitable CRITIC weighting method, hence it’s more applicable to the research object. The CRITIC-TOPSIS model is put into case study to verify its practicability and rationality.

2. Indexes
In accordance with the operation and business modes of distributed energy generation projects, an index system was built as shown in Table 1. It is a remarkable fact that this index system is closely related with China’s energy policy, hence indexes like “Financial subsidies” were included and calculated according to China’s present pricing mechanism [5].
Table 1. Economic benefit evaluation indexes

| Indexes                              | Codes |
|--------------------------------------|-------|
| Income per year/thousand yuan        | $I_1$ |
| Asset-liability ratio/%              | $I_2$ |
| Net present value/thousand yuan      | $I_3$ |
| Internal rate of return/%            | $I_4$ |
| Payback period/year                  | $I_5$ |
| Return on investment/%               | $I_6$ |
| Financial subsidies/(yuan/kWh)       | $I_7$ |
| Expected wind curtailment/%          | $I_8$ |
| Expected solar energy curtailment    | $I_9$ |
| Load forecast accuracy               | $I_{10}$ |
| Customer satisfaction rate           | $I_{11}$ |
| Income per year/thousand yuan        | $I_1$ |

3. Economic benefit evaluation model

3.1. The CRITIC weighting method

CRITIC (short for Criteria Importance Through Intercriteria Correlation) weighting method, which uses comparativeness and conflict features between indexes to evaluate weight of different indexes, is quite effective in dealing with indexes which are closely related. Due to the tight relation between economic indexes, CRITIC method is suitable for the economic evaluation of distributed energy generation projects.

The CRITIC method is calculated as follows:

1) Comparativeness and conflict features description:

$$CAC_k = \sigma_k \sum_{k=1}^{m} (1 - |R_k|)$$ (1)

$CAC_k$ is the CRITIC criteria of index $K$, $R_k$ represents the correlation coefficient between different indexes. The number of indexes is $m$. $\sigma_k$ is the standard deviation of index $K$.

2) Weight calculation:

$$W_k = \frac{CAC_k}{\sum_{k=1}^{m} CAC_k}$$ (2)

$W_k$ is the weight of different indexes.

3.2. The TOPSIS model

After the CRITIC weighting calculation, the TOPSIS model can be built as follows:

1) Index data normalization

The normalization process in this paper was carried out using averaging method to remove the dimensional difference between indexes:

$$k'_{ij} = \frac{k_{ij}}{\frac{1}{m} \sum_{j=1}^{m} k_{ij}}$$ (3)
2) Weighted matrix

The normalized data can be weighted and form the weighted index matrix:

\[ K' = (w_{kkij})_{i\times j} \]  

(4)

3) Euclidean distance calculation

A positive ideal solution and a negative ideal solution for each index can be defined as \( k_j^+ \) and \( k_j^- \), and Euclidean distance for each index can be calculated [6] :

\[ e_i^{\text{best}} = \sqrt{\sum_{j=1}^{n} w_j (k_{ij}^+ - k_j^+)^2} \]  

(5)

\[ e_i^{\text{worst}} = \sqrt{\sum_{j=1}^{n} w_j (k_{ij}^- - k_j^-)^2} \]  

(6)

4) Comprehensive distance calculation

The comprehensive distance result should be calculated using formula (7):

\[ E_i = e_i^{\text{best}} / (e_i^{\text{worst}} + e_i^{\text{best}}) \]  

(7)

\( E_i \) represents comprehensive distance, the project with highest \( E_i \) value is the most optimized projects [7].

4. Case study

The model established in this paper will be used in the distributed energy generation projects in North China. Project A is equipped with energy storage devices and will participate in electricity market. Power generated from Project B will be used to fulfill the users’ power demand and surplus power will be transmitted to main grid. Project C will fully participate in electricity market. Project D is established to provide power to the main grid only. The data is shown in Table 2.

| Table 2. Data |
|---------------|
| Indexes | A | B | C | D |
| Income per year/thousand yuan | 2561 | 1980 | 2154 | 2016 |
| Asset-liability ratio/% | 30.1 | 35.2 | 30.5 | 32.4 |
| Net present value/thousand yuan | 8946 | 8541 | 8849 | 8847 |
| Internal rate of return/% | 19.1 | 15.2 | 18.4 | 16.5 |
| Payback period/year | 7.5 | 9.1 | 8.2 | 7.9 |
| Return on investment/% | 8.5 | 9.5 | 8.6 | 8.9 |
| Financial subsidies/(yuan/kWh) | 0.32 | 0.42 | 0.32 | 0.42 |
| Expected wind curtailment/% | 12.8 | 9.2 | 10.8 | 4.6 |
| Expected solar energy curtailment/% | 19.5 | 9.5 | 15.4 | 4.2 |
| Load forecast accuracy/% | 85.2 | 98.2 | 80.4 | 99.5 |
| Customer satisfaction rate/% | 95.2 | 99.9 | 95.8 | 99.9 |

The weight of indexes can be obtained through CRITIC method, as it’s shown in Table 3.
Table 3. Weight of indexes

| Indexes                      | Weight |
|------------------------------|--------|
| Income per year              | 0.077  |
| Asset-liability ratio        | 0.038  |
| Net present value            | 0.014  |
| Internal rate of return      | 0.071  |
| Payback period               | 0.045  |
| Return on investment         | 0.026  |
| Financial subsidies          | 0.086  |
| Expected wind curtailment    | 0.226  |
| Expected solar energy curtailment | 0.346 |
| Load forecast accuracy       | 0.057  |
| Customer satisfaction rate   | 0.015  |
| Income per year              | 0.077  |

After the normalization process, the weighted indexes can be calculated and summarized in Table 4.

Table 4. Weighted indexes

| Indexes                                      | A      | B      | C      | D      |
|----------------------------------------------|--------|--------|--------|--------|
| Income per year/thousand yuan                | 0.023  | 0.017  | 0.019  | 0.018  |
| Asset-liability ratio/%                      | 0.009  | 0.010  | 0.009  | 0.010  |
| Net present value/thousand yuan              | 0.004  | 0.003  | 0.004  | 0.004  |
| Internal rate of return/%                    | 0.019  | 0.016  | 0.019  | 0.017  |
| Payback period/year                          | 0.010  | 0.013  | 0.011  | 0.011  |
| Return on investment/%                       | 0.006  | 0.007  | 0.006  | 0.007  |
| Financial subsidies/(yuan/kWh)               | 0.019  | 0.024  | 0.019  | 0.024  |
| Expected wind curtailment/%                  | 0.077  | 0.056  | 0.065  | 0.028  |
| Expected solar energy curtailment/%          | 0.139  | 0.068  | 0.110  | 0.030  |
| Load forecast accuracy/%                     | 0.013  | 0.015  | 0.013  | 0.016  |
| Customer satisfaction rate/%                 | 0.004  | 0.004  | 0.004  | 0.004  |

Positive ideal solutions and negative ideal solutions for each index are shown in Table 5.

Table 5. Positive ideal solution and negative ideal solutions for each index

| Indexes                                      | $k_i^+$ | $k_i^-$ |
|----------------------------------------------|---------|---------|
| Income per year/thousand yuan                | 0.023   | 0.017   |
| Asset-liability ratio/%                      | 0.009   | 0.010   |
| Net present value/thousand yuan              | 0.004   | 0.003   |
| Internal rate of return/%                    | 0.019   | 0.016   |
| Payback period/year                          | 0.010   | 0.013   |
| Return on investment/%                       | 0.007   | 0.006   |
| Financial subsidies/(yuan/kWh)               | 0.024   | 0.019   |
| Expected wind curtailment/%                  | 0.028   | 0.077   |
| Expected solar energy curtailment/%          | 0.030   | 0.139   |
| Load forecast accuracy/%                     | 0.016   | 0.013   |
| Customer satisfaction rate/%                 | 0.004   | 0.004   |

The $e_{\text{worst}}$, $e_{\text{best}}$, and $E_i$ of each project is shown in Table 6:
Table 6. $e_{\text{worst}}$ and $e_{\text{best}}$ value

| Projects | A   | B   | C   | D   |
|----------|-----|-----|-----|-----|
| $e_{\text{best}}$ | 0.120 | 0.047 | 0.088 | 0.006 |
| $e_{\text{worst}}$ | 0.007 | 0.075 | 0.032 | 0.120 |
| $E_i$     | 0.944 | 0.388 | 0.735 | 0.044 |

As the result shows, Project A has the highest $E_i$ value, which means the economic benefit of Project A is the highest. Project A should be the best mode to carry out distributed generation projects.

5. Conclusion

Distributed generation projects, which is capable of fulfilling users’ power demand in a more flexible and controllable way, has now become more and more critical in promoting new energy generation and demand side management. The economic benefit evaluation and selection of different project modes is important in the early stage of project implementation. This paper has built the economic evaluation index system according to the features of distributed generation projects. Besides, the TOPSIS model was further optimized using CRITIC weighting method, which is more suitable to the economic benefit evaluation of distributed generation projects. The practicability and rationality of the improved model were proved through case study, and the suitable mode for the project presented in this paper has been derived as well.

References

[1] Feifei Y, Xingang Z 2018 Policies and economic efficiency of China's distributed photovoltaic and energy storage industry Energy. 154 221-230.
[2] L. Mehigan, J. P. Deane, B. P. Ó. Gallachór and V. Bertsch 2017 A review of the role of distributed generation (DG) in future electricity systems Energy. 163 822-836.
[3] Yalin H, Lennart S 2017 Evaluation of economic regulation in distribution systems with distributed generation Energy. 126 192-201.
[4] Muttaqi K M, An D. T. Le, J. Aghaei, E. Mahboubi-Moghaddam and G. Ledwich 2016 Optimizing distributed generation parameters through economic feasibility assessment Appl Energ. 165 893-903.
[5] Jeongyoon O, Choongwan K, Taehoon H and Seung H C 2018 An integrated model for estimating the techno-economic performance of the distributed solar generation system on building façades: Focused on energy demand and supply Appl Energ. 228 1071-1090
[6] Mohammad Y 2018 Risk assessment based on novel intuitionistic fuzzy-hybrid-modified TOPSIS approach Safety Sci. 110 438-448.
[7] Huimin T, Yong S, and Peiwu D 2019 Public blockchain evaluation using entropy and TOPSIS Expert Syst Appl 117 204-210.