POST-EVALUATION OF THE ENERGY TRUSTEESHIP PROJRCT OF REGIONAL DISTRIBUTION NETWORK

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ARTICLE DETAILS

ABSTRACT

Article History:

Received 02 october 2017
 Accepted 06 october 2017
 Available online 11 october 2017

Keywords:

Regional distribution network,
 Energy trusteeship mode, Post-
 evaluation

In recent years, Chinese government put more emphasis on the energy conservation and emissions reduction of power system, the power enterprises and energy-saving service companies began to pay attention to the application of energy performance contracting in the energy-saving reconstructs of the regional distribution network. The energy trusteeship is a perfect mode for prompting the diminishing line loss and economizing power energy of regional distribution network. In order to evaluate the implementation effect of the energy trusteeship project of regional distribution network, the paper designed the post-evaluation index system from the four stages, namely, decision-making stage, preparation phase, implementation stage and operation phase, based on the lifecycle theory; And then used the analytic hierarchy process to calculate the weight of post-evaluation index; Finally, the post-evaluation model of the energy trusteeship project of regional distribution network was constructed. The post-evaluation mode contributed to improve the investment efficiency for the future energy trusteeship projects of regional distribution system.

1. INTRODUCTION

With the application of energy performance contracting (EPC) in regional distribution network, as an important mode of EPC, the energy trusteeship mode promoted the innovation and development of the energy saving service mode of electrical network operation [1, 2]. At present, only few literatures researched the energy trusteeship mode, especially its post evaluation. Most scholars were mainly focus on large-scale power grid construction and evaluation on the improved construction project. As for the evaluation of large-scale power engineering projects, the analytic hierarchy process (AHP) method, Delphi method, fuzzy comprehensive evaluation and other methods were often used. These methods were able to evaluate these sub-projects rapidly and accurately. Based on these, the logical framework method was used to do further comprehensive analysis. It can take fully advantage of the overall approach and avoid the shortcomings of single method [3-6].

The indicator system is the foundation of post evaluation model, and many literatures designed the evaluation index system. Lu Lei indicated that the index system should be designed based on the principles of comprehensive, simplicity, relative independence, and objectivity [7,8]. The weights are the key factors that influence the project evaluation, and the index weight was determined by the analytic hierarchy method level [9, 10]. Based on that, the paper would design the post-evaluation index system, obtain the judgment matrixes of weights based on the AHP and the post evaluation experience, and then estimate the post evaluation index weights. Finally the paper constructed the post evaluation mode of the energy trusteeship of regional distribution network.

2. The design of post evaluation index system

The energy trusteeship project of regional distribution network can be divided into four stages based on the project cycle theory, namely the stage of decision-making, preparation, energy-saving renovation and operation. The paper designed the post-evaluation index system based on these four stages, in order to evaluate the process and effect of the energy trusteeship project implementation of regional distribution system objectively and scientifically.

2.1 The decision-making stage

Although the cost of the project decision-making phase is not high, it takes comparatively long time to complete the project establishment work in the stage. The process and quality of the work in the stage has an important influence on the project investment benefit and even determine if the project is a success or a failure. Therefore, the post-evaluation of the decision-making stage (B_1) is an important part of project overall post-evaluation.

The post-evaluation index system of the decision-making stage was designed from the three dimensions of the scheme drafting capacity (SDC_{C11}), project deciding capacity (PDC_{C12}) and plan implementation capacity (PIC_{C13}). The specific post-evaluation indexes of the three dimensions were shown in the Table 1.

Table 1. Post-evaluation index system of the decision-making stage

Dimension	post-evaluation index
SDC_{C11}	loss reduction estimation accuracy rate (LER)
	investment estimation accuracy rate (IER)
	Loss reduction scheme responsivity (LSR)
PDC_{C12}	goal achievement rate (GAR)
PIC_{C13}	project alteration rate (PAR)
	project completion rate (PCR)

2.2 The preparation stage

The preparation stage determines the quality of the project implementation preparation work and affects the construction and operation of the energy trusteeship project of regional distribution network. Orderly and scientific preparation work contributes to the smooth implementation of the project. So the post-evaluation of the preparation stage (B_2) is an important part of the project overall post-evaluation.

The paper designed the post-evaluation index system of the preparation stage based on the project program design (PPD_{C21}), project bidding and tendering (PBT_{C22}), project investment and financing (PIF_{C23}) and project start preparation (PSP_{C24}). The specific post-evaluation indexes of the above four dimensions were shown in the Table 2.

Table 2. Post-evaluation index system of the preparation stage

Dimension	post-evaluation index
PPD_{C21}	program design depth (PSD) program construction instructions (PCI)
PBT_{C22}	investment and financing program (IFP) project-funding preparations (PFP)
PIF_{C23}	project bidding work (PBW) project tendering work (PTW)
PSP_{C24}	contract signature (CTS) project material preparation (PMP)

2.3 The energy-saving renovation stage

In the energy-saving renovation stage, the participants need to devote a large sum of utilize human, material and financial resources, and the management in the phase is important to the project performance. Therefore, the post-evaluation of the energy-saving renovation stage (B_3) is the indispensable portion in the project overall post-evaluation. In order to evaluate the implementation work, the post-evaluation index system of the implementation stage was designed from the five dimensions of the Project schedule control (PSC_{C31}), Project quality control (PQC_{C32}), Project Investment Control (PIC_{C33}), Project Safety Management (PSM_{C33}), and Project contract management (PCM_{C35}). The specific post-evaluation indexes of the five dimensions were shown in the Table 3.

Table 3. Post-evaluation index system of the energy-saving renovation stage

Dimension	post-evaluation index
PSC_{C31}	percentage complete on schedule (PCS)
PQC_{C32}	control point detection pass rate (CDR)
PIC_{C33}	cost change rate (CCR) fund payment and management (FPM)
PSM_{C34}	equipment safety management (ESM) person safety management (PSM)
PCM_{C35}	contract terms implementation (CTI) contract terms modification (CTM)

2.4 The operation stage

The state of operation is the most able to reflect the project implementation effect of the energy trusteeship projects of regional distribution system directly. So the post-evaluation of the operation stage (B_4) is the a key component of the project overall post-evaluation.

The post-evaluation index system of the operation phase was designed from the six dimensions of the project financial benefits (PFB_{C41}), energy-saving environmental benefits (EEB_{C42}), project social benefits (PSB_{C43}), distribution network security (DNS_{C44}), distribution network operation (DNO_{C45}), project operation and management (POM_{C46}). The specific post-evaluation indexes of the above six dimensions were shown in the Table 4.

Table 4. Post-evaluation index system of the operation stage

Dimension	post-evaluation index
PFB_{C41}	internal rate of return (IRR) investment payback period (IPO) net present value (NPV) investment profit ratio (IPR)
EEB_{C42}	loss reduction rate (LRR) power loss reduction (PLR)
PSB_{C43}	Energy saving transformers proportion (ETP) employment contribution (ECN) energy-saving technology improvement (ETI) promoting economic development (PED)
DNS_{C44}	voltage qualified rate (VQR) power supply reliability (PSR) power equipment management (PEM)
DNO_{C45}	energy measurement management (EMM) energy-saving management (ESM) reactive power compensation capability (RPC)
POM_{C46}	power load stability (PLS) transformer load rate (TLR)

2.5 The post-evaluation index system

The post-evaluation index system of the energy trusteeship project of the regional distribution network (NTP_{RDN}) was constructed on basis of selecting the forty post-evaluation indexes from the four stages of the decision-making, preparation, energy-saving renovation and operation. The post-evaluation index system was shown in the Fig. 1.

Fig1. Post-evaluation index system of the NTP_{RDN}

3. The post-evaluation model construction of the regional distribution network energy trusteeship project

On the basis of the designing of post-evaluation index system, the experts and scholars, technical personnel and management personnel of the relevant areas was chose to investigate the relative importance of post evaluation indexes in the form of questionnaires, and collected the evaluation data of the post-evaluation indexes of the energy trusteeship project of the regional distribution network. The paper sorted out the weight judgment matrix of post-evaluation indexes by analyzing the evaluation data based on the AHP.

3.1 The first-level post-evaluation index weight

The first-order index weight judgment matrix $A-B$ of post-evaluation:

$$A-B = \begin{bmatrix} 1 & 3 & 1/2 \\ 1/3 & 1 & 1/3 \\ 2 & 3 & 1 \\ 2 & 3 & 1 \end{bmatrix}$$

The paper used the MATLAB to calculate the first-level index weight of the post-evaluation of the energy trusteeship project of regional distribution network, the result is as follow:

$$W^{(1)} = (0.2094, 0.0982, 0.3462, 0.3462)$$

The consistency test index of the weight judgment matrix is 0.023, and less than 0.1, which indicates that the weight judgment matrix satisfies the consistency test, and the weight calculation result is scientific and reliable.

3.2 The second-level evaluation index weight

The second-level index weight judgment matrix B_1-C of the decision-making stage post-evaluation:

$$B_1-C = \begin{bmatrix} 1 & 1/2 & 1/2 \\ 2 & 1 & 1/2 \\ 2 & 2 & 1 \end{bmatrix}$$

The second-level index weight judgment matrix B_2-C of the preparation stage post-evaluation:

$$B_2-C = \begin{bmatrix} 1 & 2 & 3 & 4 \\ 1/2 & 1 & 3 & 3 \\ 1/3 & 1/3 & 1 & 2 \\ 1/4 & 1/3 & 1/2 & 1 \end{bmatrix}$$

The second-level index weight judgment matrix B_3-C of the energy-saving renovation stage post-evaluation:

$$B_3-C = \begin{bmatrix} 1 & 1/3 & 1/2 & 1/2 & 1 \\ 3 & 1 & 2 & 2 & 3 \\ 2 & 1/2 & 1 & 1/2 & 2 \\ 2 & 1/2 & 2 & 1 & 2 \\ 1 & 1/3 & 1/2 & 1/2 & 1 \end{bmatrix}$$

The second-level index weight judgment matrix $B_4 - C$ of the operation stage post-evaluation:

$$B_4 - C = \begin{bmatrix} 1 & 3 & 2 & 2 & 2 & 4 \\ 1/3 & 1 & 1/2 & 1/3 & 1/2 & 3 \\ 1/2 & 2 & 1 & 1/2 & 2 & 4 \\ 1/2 & 3 & 2 & 1 & 2 & 4 \\ 1/2 & 2 & 1/2 & 1/2 & 1 & 3 \\ 1/4 & 1/3 & 1/4 & 1/4 & 1/3 & 1 \end{bmatrix}$$

And then used MATLAB to calculate the second-level index weights of the post-evaluation of the decision-making stage, preparation phase, energy-saving renovation stage and operation phase respectively, the results are as follow:

$$W_1^{(2)} = (0.196, 0.311, 0.493)$$

$$W_2^{(2)} = (0.459, 0.305, 0.143, 0.093)$$

$$W_3^{(2)} = (0.108, 0.365, 0.180, 0.239, 0.108)$$

$$W_4^{(2)} = (0.305, 0.093, 0.178, 0.241, 0.134, 0.049)$$

The consistency test index of the above four weight judgment matrixes is:

$$CR = CI/RI = (0.052, 0.030, 0.016, 0.032)$$

The consistency test indexes of the above weight judgment matrixes are less than 0.1. Therefore, the consistency tests of the four judgment matrixes could be adopted, and the calculation result of post-evaluation indexes weight is scientific and reliable.

3.2 The third-level evaluation index weight

(1) The decision-making stage

The third-order index weight judgment matrix $C_{11} - D$ and $C_{13} - D$ of the post-evaluation of the scheme drafting capacity and plan implementation capacity are as follow:

$$C_{11} - D = \begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix} \quad C_{13} - D = \begin{bmatrix} 1 & 1/2 \\ 2 & 1 \end{bmatrix}$$

And then used MATLAB to calculate the third-order index weights of the post-evaluation of the scheme drafting capacity and plan implementation capacity respectively, the results are as follow:

$$W_{11}^{(3)} = (0.540, 0.297, 0.163) \quad W_{13}^{(3)} = (0.333, 0.667)$$

The consistency test index of the weight judgment matrix $C_{11} - D$ is $CR = CI/RI = 0.0089 < 0.1$. The calculation result is reliable. The weight judgment matrix $C_{13} - D$ doesn't need consistency check. As for the dimension of project deciding capacity has only a third-order index, so the GAR index weight is $W_{12}^{(3)} = (1.000)$

(2) The preparation stage

The third-order index weight judgment matrix $C_{21} - D$, $C_{22} - D$, $C_{23} - D$ and $C_{24} - D$ of the post-evaluation of project program design, project bidding and tendering, project investment and financing and project start preparation are as follow:

$$C_{21} - D = \begin{bmatrix} 1 & 2 \\ 1/2 & 1 \end{bmatrix} \quad C_{22} - D = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

$$C_{23} - D = \begin{bmatrix} 1 & 1/2 \\ 2 & 1 \end{bmatrix} \quad C_{24} - D = \begin{bmatrix} 1 & 1/2 \\ 2 & 1 \end{bmatrix}$$

The weight calculation results are as follow:

$$W_{21}^{(3)} = (0.667, 0.333) \quad W_{22}^{(3)} = (0.500, 0.500)$$

$$W_{23}^{(3)} = (0.333, 0.667) \quad W_{23}^{(3)} = (0.333, 0.667)$$

The above four weight judgment matrix doesn't need consistency check.

(3) The energy-saving renovation stage

The third-order index weight judgment matrix $C_{33} - D$, $C_{34} - D$ and $C_{35} - D$ of post-evaluation of the project program design, project bidding and tendering, project investment and financing and project start preparation are as follow:

$$C_{33} - D = \begin{bmatrix} 1 & 2 \\ 1/2 & 1 \end{bmatrix} \quad C_{34} - D = \begin{bmatrix} 1 & 1/2 \\ 2 & 1 \end{bmatrix} \quad C_{35} - D = \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix}$$

The weight calculation results are as follow:

$$W_{33}^{(3)} = (0.667, 0.333) \quad W_{34}^{(3)} = (0.333, 0.667)$$

$$W_{35}^{(3)} = (0.750, 0.250)$$

The dimensions of the Project schedule control and project quality control have only a third-order index respectively, so the index weight of both PCS and CDR are as follow:

$$W_{31}^{(3)} = W_{32}^{(3)} = (1.000)$$

(4) The operation stage

The third-order index weight judgment matrix $C_{41} - D$, $C_{42} - D$, $C_{43} - D$, $C_{44} - D$, $C_{45} - D$ and $C_{46} - D$ of the project financial benefits, energy-saving environmental benefits, project social benefits, distribution network security, distribution network operation, project operation and management are as follow:

$$C_{41} - D = \begin{bmatrix} 1 & 2 & 2 & 2 \\ 1/2 & 1 & 1/2 & 1/2 \\ 1/2 & 2 & 1 & 1/2 \\ 1/2 & 2 & 2 & 1 \end{bmatrix} \quad C_{42} - D = \begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix}$$

$$C_{43} - D = \begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix} \quad C_{44} - D = \begin{bmatrix} 1 & 1/2 \\ 2 & 1 \end{bmatrix}$$

$$C_{45} - D = \begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix} \quad C_{46} - D = \begin{bmatrix} 1 & 1/2 & 1/2 \\ 2 & 1 & 1/2 \\ 2 & 2 & 1 \end{bmatrix}$$

The weight calculation results are as follow:

$$W_{41}^{(3)} = (0.391, 0.138, 0.195, 0.276)$$

$$W_{42}^{(3)} = (0.333, 0.528, 0.140)$$

$$W_{43}^{(3)} = (0.163, 0.540, 0.297)$$

$$W_{44}^{(3)} = (0.333, 0.667)$$

$$W_{45}^{(3)} = (0.333, 0.667)$$

$$W_{46}^{(3)} = (0.196, 0.311, 0.493)$$

The consistency test indexes of the above judgment matrices are less than 0.1, so the results are scientific and reliable.

3.4 The post-evaluation model

According to the calculation result of post-evaluation index weight, the post-evaluation model of the energy trusteeship project of the regional distribution network was obtained:

$$\begin{aligned} \text{Post evaluation}(A) &= W^{(1)} \bullet B \\ &= (0.209, 0.098, 0.346, 0.346) \bullet (B_1, B_2, B_3, B_4)^T \\ &= 0.209 \times B_1 + 0.098 \times B_2 + 0.346 \times B_3 + 0.346 \times B_4 \end{aligned} \quad (1)$$

(1) The post-evaluation sub model of decision-marking stage (B_1):

$$\begin{aligned} \text{Decision-marking post-evaluation}(B_1) &= W_1^{(2)} \bullet C_1^T \\ &= 0.196 \times SDC_C_{11} + 0.311 \times PDC_C_{12} + 0.493 \times PIC_C_{13} \end{aligned} \quad (2)$$

Where,

$$\begin{aligned} SDC_C_{11} &= W_{11}^3 \bullet D_{11}^T \\ &= 0.540 \times LER + 0.297 \times IER + 0.163 \times LSR \end{aligned} \quad (3)$$

$$PDC_C_{12} = 1.000 \times GAR \quad (4)$$

$$\begin{aligned} PIC_C_{13} &= W_{13}^3 \bullet D_{13}^T \\ &= 0.333 \times PAR + 0.667 \times PCR \end{aligned} \quad (5)$$

(2) The post-evaluation sub model of preparation stage (B_2):

$$\begin{aligned} \text{Preparation post-evaluation}(B_2) &= W_2^{(2)} \bullet C_2^T \\ &= 0.459 \times PPD_C_{21} + 0.305 \times PBF_C_{22} \\ &\quad + 0.143 \times PIT_C_{23} + 0.093 \times PSP_C_{24} \end{aligned} \quad (6)$$

Where,

$$\begin{aligned} PPD_C_{21} &= W_{21}^3 \bullet D_{21}^T \\ &= 0.667 \times PSD + 0.333 \times PCI \end{aligned} \quad (7)$$

$$\begin{aligned} PBF_C_{22} &= W_{22}^3 \bullet D_{22}^T \\ &= 0.5 \times IFP + 0.5 \times PFP \end{aligned} \quad (8)$$

$$\begin{aligned} PIF_C_{23} &= W_{23}^3 \bullet D_{23}^T \\ &= 0.667 \times PBW + 0.333 \times PTW \end{aligned} \quad (9)$$

$$\begin{aligned} PSP_C_{24} &= W_{24}^3 \bullet D_{24}^T \\ &= 0.667 \times CTS + 0.333 \times PMP \end{aligned} \quad (10)$$

(3) The post-evaluation sub model of energy-saving renovation stage (B_3):

$$\begin{aligned} \text{Energy-saving renovation post-evaluation}(B_3) &= W_3^{(2)} \bullet C_3^T \\ &= 0.108 \times PSC_C_{31} + 0.365 \times PQC_C_{32} \\ &\quad + 0.180 \times PIC_C_{33} + 0.239 \times PSM_C_{34} + 0.108 \times PCM_C_{35} \end{aligned} \quad (11)$$

Where,

$$PSC_C_{31} = 1.000 \times PCS \quad (12)$$

$$PQC_C_{32} = 1.000 \times CDR \quad (13)$$

$$\begin{aligned} PIC_C_{33} &= W_{33}^3 \bullet D_{33}^T \\ &= 0.667 \times CCR + 0.333 \times FPM \end{aligned} \quad (14)$$

$$\begin{aligned} PSM_C_{34} &= W_{34}^3 \bullet D_{34}^T \\ &= 0.333 \times ESM + 0.667 \times PSM \end{aligned} \quad (15)$$

$$\begin{aligned} PCM_C_{35} &= W_{35}^3 \bullet D_{35}^T \\ &= 0.75 \times CPM + 0.25 \times COC \end{aligned} \quad (16)$$

(4) The post-evaluation sub model of operation stage (B_4):

$$\begin{aligned} \text{Operation post-evaluation}(B_4) &= W_4^{(2)} \bullet C_4^T \\ &= 0.305 \times PFB_C_{41} + 0.093 \times EEB_C_{42} \\ &\quad + 0.178 \times PSB_C_{43} + 0.241 \times DNS_C_{44} \\ &\quad + 0.134 \times DNO_C_{45} + 0.049 \times POM_C_{46} \end{aligned} \quad (17)$$

Where,

$$PFB_C_{41} = W_{41}^3 \bullet D_{41}^T \quad (18)$$

$$\begin{aligned} &= 0.391 \times IRR + 0.138 \times IPO + 0.195 \times NPV + 0.276 \times IPR \\ EEB_C_{42} &= W_{42}^3 \bullet D_{42}^T \end{aligned} \quad (19)$$

$$\begin{aligned} &= 0.333 \times LRR + 0.528 \times PLR + 0.140 \times ETP \\ PSB_C_{43} &= W_{43}^3 \bullet D_{43}^T \end{aligned} \quad (20)$$

$$\begin{aligned} &= 0.163 \times ECN + 0.540 \times ETI + 0.297 \times PED \\ SRD_C_{44} &= W_{44}^3 \bullet D_{44}^T \end{aligned} \quad (21)$$

$$\begin{aligned} &= 0.333 \times VQR + 0.667 \times PSR \\ DNO_C_{45} &= W_{45}^3 \bullet D_{45}^T \end{aligned} \quad (22)$$

$$\begin{aligned} &= 0.540 \times PEM + 0.297 \times EMM + 0.163 \times ESE \\ POM_C_{46} &= W_{46}^3 \bullet D_{46}^T \end{aligned} \quad (23)$$

4. Conclusions

The paper designed the post-evaluation index system of the energy trusteeship project of the regional distribution system, and then calculated the weight after collecting evaluation data of the relative importance of evaluation index on basis of AHP. Finally, the post-evaluation mode of the energy trusteeship of regional distribution network was constructed. The research of the paper could provide the scientific evidence and reference for improving the investment efficiency of energy trusteeship project of regional distribution network in China.

Acknowledgements

This paper is supported by "Science and technology project funding by State Grid Corporation of China (Grant No. 27KJ010501C1016320140000)".

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