Research on the Optimization Technology of the Production Technical Transformation Reserve Project of The Distribution Network Based on the Particle Swarm Algorithm

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Abstract: With the continuous development of social economy, the investment and construction scale of distribution network production technical transformation projects is increasing day by day. In this context, how to scientifically plan the investment time sequence of the distribution network production technical transformation project is of great significance for ensuring the safe operation of the power grid. However, the preferred selection of the production technical transformation projects of the distribution network depends more on the experience judgment of technical personnel and lacks certain scientific theoretical basis. Therefore, this paper puts forward the optimization technology of the distribution network production technical transformation reserve project based on the particle group algorithm, fully considering the impact of the reserve project after the completion of other reserve projects, so as to dynamically rank and optimize each reserve project, and further improve the investment efficiency and benefit of the distribution network production technical transformation project.

Keywords: distribution network, production technology transformation, particle swarm optimization, comprehensive weighting, project optimization technology

1. Introduction

It is of great significance to support the safe and reliable operation of the power grid to further improve the scientific decision-making, the efficiency of investment fund utilization and the efficiency of investment efficiency.

Literature [1] from the four dimensions of economic benefit, construction urgency, implementation effect, power supply reliability on the project, so as to build the project evaluation system, using the improved level analysis method to optimize the planning projects, and verify the scientific and rationality of the method in the case analysis. Literature [2] uses the index weight combination empowerment method based on hierarchical analysis method and coefficient of variation method to optimize the construction of investment optimization model, so as to realize the standard management and investment optimization of power grid production technical transformation projects. Literature [3] In view of the shortcomings of decentralized evaluation objectives and strong subjectivity of existing power grid science and technology

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projects, this paper establishes a high-quality development index system of power grid science and technology projects, and proposes a preferred ranking method for the evaluation of power grid science and technology projects (PT-TOPSIS). Through example calculation, the proposed method, on the basis of overcoming the existing evaluation method, has better differentiation and decision accuracy, which can provide a more scientific and objective basis for relevant departments to make decisions. Literature [4] puts forward some suggestions from the aspects of management concept innovation and big data application. Literature [5] to improve power grid company production project implementation efficiency, improve capital investment, especially for the future development trend to solve the problem of capital constrained project optimization, in accordance with the hierarchical analysis to determine the specific indicators, and according to the index weight and model design ideas and process, design the production project optimization sorting model. Literature [6] uses reliability engineering techniques and LCC to reduce losses due to unreliable processes and equipment. Literature [7] An asset management system established in a transmission and distribution network using the LCC method. Literature [8] shows a method for selecting the design and parameters of back-to-back devices in a DC transmission system based on LCC and reliability.

In summary, the current ranking of power grid projects mainly has the following shortcomings: first, the calculation of index weights is mainly based on the self-experience of personnel; Second, the efficiency of project capital utilization is not comprehensively considered; Third, the contribution to the operation of the power grid after the project is put into operation is not considered.

2. Indicator building

The comprehensive evaluation index system of the construction effectiveness of the production technology transformation reserve project constructed in this paper is shown in Table 1 below.

Table 1. Comprehensive evaluation index system of contribution of production technical transformation reserve project of distribution network.

Level 1 indicators	Secondary indicators
Network frame improvement contribution degree	The N-1 criterion satisfaction degree
	Line contact rate
Contribution to the power supply capacity improvement	Load transfer capacity
Operational efficiency to improve the contribution degree	line loss rate
	Voltage pass rate
	power distribution reliability
Benefit contribution	Electricity efficiency
	Energy conservation and emission reduction benefits
Customer satisfaction to increase the contribution degree	Customer satisfaction

As can be seen from Table 1, the evaluation index system of distribution network reserve project is mainly constructed from five dimensions: grid improvement, power supply capacity improvement, operation efficiency improvement, benefit contribution and customer satisfaction.

3. Model building

3.1 Calculation method of index weight

Using the combinatorial weighting method based on the moment estimation theory, d samples and q-d samples are extracted from the subjective weight population and the objective weight population respectively, and the sample mean and the equivalent population expectation and variance of the second-order origin moment are used to meet the deviation between the combined weight w_j and the q subjective and objective weights for the q weight samples of each attribute G_j, and the relative importance of the subjective and objective weights α and β of different attributes should be considered, then the combined weights are solved as follows:

$$\begin{cases} \min H(w_j) = a\sum_{h=1}^{d}(w_j - w_{hj})^2 + \beta\sum_{z=d+1}^{q}(w_j - w_{zj})^2 \\ s.t. 0 \le w_j \le 1, 1 \le j \le m \end{cases} \quad (1)$$

(1) The Delphi method and hierarchical analysis method are used to empower all the evaluation indicators of the reserve items. As the two samples of the subjective weight, the subjective weight set of each index is obtained as follows:

$$W_H = \{w_{hj} | 1 \le h \le d, 1 \le j \le y\} \quad (2)$$

Where w_{hj} is the h-t h kind of weighting method, the weight vector of the j-t h index, *d* is the number of methods of the subjective weighting method, and *y* is the number of evaluation indicators. Where, for any h, there is $\sum_{j=1}^{y} w_{hj} = 1, w_{hj} \ge 0$.

(2) The entropy weight method and the mean variance method are used to empower all the evaluation indexes of the reserve items. As the two samples of the objective weight, the objective weight set of each index is obtained:

$$W_Z = \{w_{zj} | d+1 \le z \le q, 1 \le j \le y\} \quad (3)$$

Where w_{zj} is the $z-th$ type of weighting method, the weight vector of the $j-th$ index, q is the total number of subjective and objective weighting methods, $q-d$ is the number of methods of objective weighting, and y is the number of evaluation indicators, where, for any z, there is $\sum_{j=1}^{y} w_{zj} = 1, w_{zj} \ge 0$.

(3) According to the moment estimation theory, the subjective weight expectation value $E(w_{hj})$ and the objective weight expectation value $E(w_{zj})$ of each evaluation index are calculated separately:

$$E\left(w_{hj}\right)=\frac{\sum_{h=1}^{d} w_{hj}}{d}, 1 \le j \le y \tag{4}$$

$$E\left(w_{zj}\right)=\frac{\sum_{z=d+1}^{q} w_{zj}}{q-d}, 1 \le j \le y \tag{5}$$

(4) Calculate the relative importance coefficient of subjective weight and objective weight α_j and β_j;

$$\alpha_j=\frac{E\left(w_{hj}\right)}{E\left(w_{hj}\right)+E\left(w_{zj}\right)} \tag{6}$$

$$\beta_j=\frac{E\left(w_{zj}\right)}{E\left(w_{hj}\right)+E\left(w_{zj}\right)} \tag{7}$$

(5) Calculate the relative importance of the subjective and objective weights of all the evaluation indicators for the reserve items α and β:

$$\alpha=\frac{\sum_{j=1}^{y} \alpha_j}{\sum_{j=1}^{y} \alpha_j+\sum_{j=1}^{y} \beta_j}=\frac{\sum_{j=1}^{y} \alpha_j}{y} \tag{8}$$

$$\beta=\frac{\sum_{j=1}^{y} \beta_j}{\sum_{j=1}^{y} \alpha_j+\sum_{j=1}^{y} \beta_j}=\frac{\sum_{j=1}^{y} \beta_j}{y} \tag{9}$$

(6) For each evaluation index, it is hoped that the deviation $H(w_j)$ between the combined weights w_j and q subjective and objective weights is as small as possible, so the model is optimized by the linear weighting method of equal weight, and the weight calculation formula is obtained:

$$\begin{cases} \min H(w_j)=a\sum_{h=1}^{d}(w_j-w_{hj})^2+\beta\sum_{z=d+1}^{q}(w_j-w_{zj})^2 \\ s.t.0 \le w_j \le 1, 1 \le j \le m \end{cases} \tag{10}$$

(7) The optimal weight is calculated based on the particle swarm algorithm. The specific steps are as follows:

Set the parameters of the particle swarm algorithm including population size N, maximum velocity $v_{\max}$, learning factor c_1, c_1, initial value of inertia weight $w_{\max}$, final value of inertia weight $w_{\min}$, maximum number of iterations I, and initialize the position and velocity of each particle in the population so that the number of iterations $k = 1$.

Calculate the adaptability of each particle, that is, calculate the objective function value $H(w_j)$ of each particle, so that the position of the particle after the $k-th$ iteration is x_{kId}, the velocity of the particle after the $k-th$ iteration is v_{kId}, the optimal solution found by the particle itself in the $k-th$ iteration is p_{bestId}^{k}, and the optimal solution found in the entire population in the $k-th$ iteration is g_{bestId}^{k}.

The inertia weight under the current number of iterations is calculated according to the following formula, where w^k is the inertia weight after the $k-th$ iteration:

$$w^k = w_{\max} - \frac{k}{I}(w_{\max} - w_{\min}) \quad (11)$$

Update the position and velocity of the particles according to the following formula, where r_{and1} and r_{and2} are random numbers between [0,1].

$$v_{Id}^{k+1} = w^k v_{Id}^{k} + c_1 r_{and1}(p_{bestId}^{k} - x_{Id}^{k}) + c_2 r_{and2}(g_{bestId}^{k} - x_{Id}^{k}) \quad (12)$$

$$x_{Id}^{k+1} = x_{Id}^{k} + v_{Id}^{k+1} \quad (13)$$

(8) The index contribution degree calculation model

In this paper, all indicators are converted to improvement index for dynamic ranking, and the calculation formula is as follows:

$$V_i = \frac{|V_{ai} - V_{bi}|}{V_{bi}} \quad (14)$$

In the formula, V_i is the value of the $i-th$ improvement index of the $k-th$ reserve project, M is the number of reserve items, and SK is the contribution of the $i-th$ index of the $k-th$ reserve project. Subsequently, the dynamic optimization ranking of reserve projects based on the contribution of the investment effectiveness of the distribution network unit. Index value of the degree of lifting, V_{ai} is the index value after the construction of the reserve project, and V_{bi} is the index value before the construction of the reserve project.

After calculating the improvement degree of each improvement degree index, the contribution degree of each index is calculated respectively for the transmission and distribution network reserve project and the distribution network reserve project, and the contribution degree of each index is calculated as follows:

$$S_{ik} = V_{ik} / \sum_{k=1}^{M} V_{ik} \tag{15}$$

In the formula, V_{ik} is the value of the $i-\mathrm{th}$ improvement index of the $k-\mathrm{th}$ reserve project, M is the number of reserve items, and S_{ik} is the contribution of the $i-\mathrm{th}$ index of the $k-\mathrm{th}$ reserve project. Subsequently, the dynamic optimization ranking of reserve projects based on the contribution of the investment effectiveness of the distribution network unit.

4. Empirical analysis

Explain to the distribution network project built in a certain area. The region existing A, B, C three distribution network transformation project construction, after the construction of the single network evaluation index value as shown in Table 2.

Table 2. Index of the distribution network after the implementation of a single project.

Target system		A project	B project	C project
The perfect degree of network frame	N-1 criterion satisfaction rate (%)	41.8%	43.6%	41.0%
	Load transfer capacity (MW)	312	296	256
	Line contact rate is (%)	31.8	32.9	33.7
Power supply capacity index (MW)		930	1020	950
Distribution network operation index	line loss rate	26%	24%	24%
	Voltage pass rate	75%	77%	77%
	Power supply reliability (sub / user.a)	0.18	0.19	0.18
performance indicator	Electricity efficiency (MW / ten thousand yuan)	0.17	0.21	0.19
	Energy-saving and emission-reduction benefits () $\mu g / \mathrm{m}^3$	5.1	6.2	5.8
Customer satisfaction index		13%	14%	16%

In order to calculate the index contribution, the index value before and after the construction of the reserve project is first transformed into the improvement index. The improvement index of the distribution network after the construction of a single project is as shown in Table 3.

Table 3. Improvement degree of each index of the distribution network after the implementation of a single project.

	Target system	A project	B project	C project
The perfect degree of network frame	The N-1 criterion satisfaction rate improvement degree	20.3%	25.4%	18.0%
	Improvement degree of load transfer capacity	21.9%	15.6%	0
	Line connection rate improvement degree	5.6%	5.9%	11.9%
Power supply capacity improvement degree		2.2%	12.1%	4.4%
Distribution network operation index	Line loss rate improvement	7.7%	14.2%	14.2%
	Increase the degree of qualified rate of voltage	2.7%	5.5%	5.5%
	Improvement of power supply reliability	11.1%	16.7%	11.1%
performance indicator	Electricity efficiency improvement degree (MW / ten thousand yuan)	0.17	0.21	0.19
	Improve the degree of energy conservation and emission reduction efficiency	8.3%	10.1%	9.4%
Improvement degree of customer satisfaction index		13%	14%	16%

The weight calculation results of subjective and objective empowerment methods, as shown in Table 4:

Table 4. The weight calculation results of subjective empowerment methods and objective empowerment methods are used for each index.

Target system		weight			
		Delphi method	AHP	entropy weight method	Mean variance method
Grid improvement of the degree	N-1 criterion satisfaction rate	0.12	0.10	0.08	0.10
	Load transfer capacity	0.06	0.07	0.08	0.08
	Line contact rate	0.05	0.07	0.06	0.08
Power supply capacity improvement degree		0.11	0.13	0.11	0.15
Distribution network operation index	line loss rate	0.13	0.14	0.10	0.13
	Voltage pass rate	0.08	0.09	0.10	0.10
	power distribution reliability	0.13	0.11	0.14	0.11
performance indicator	Electricity efficiency	0.08	0.10	0.11	0.08
	Energy conservation and emission reduction benefits	0.06	0.06	0.08	0.07
Customer satisfaction index		0.18	0.14	0.14	0.12

From the data in Table 4, we can derive the subjective and objective weight sets w_{hj} and w_{zj} for all indicators. Then, the subjective weight expectation value and the objective weight expectation value of each evaluation index are calculated separately, and their values are shown in Table 5:

Table 5. Expected value calculation results of the subjective and objective weights of each index.

target system		**host**observe**Weight expectation value** $E(w_{hj})$	objective**Weight expectation value** $E(w_{zj})$
Grid improvement of the degree	N-1 criterion satisfaction rate	0.10	0.08
	Load transfer capacity	0.06	0.08
	Line contact rate	0.06	0.07
Power supply capacity improvement degree		0.12	0.13
Distribution network operation index	line loss rate	0.13	0.12
	Voltage pass rate	0.09	0.10
	power distribution reliability	0.12	0.13
performance indicator	Electricity efficiency	0.09	0.09
	Energy conservation and emission reduction benefits	0.07	0.07
Customer satisfaction index		0.16	0.13

Calculate the relative importance coefficient of the subjective α_j and objective weights β_j of each index, as shown in Table 6.

Table 6. Calculation results of the relative important coefficients of the subjective weight and the objective weight of each index.

target system		**hostobserveWeight expectation value** α_j	objective**Weight expectation value** β_j
Grid improvement of the degree	N-1 criterion satisfaction rate	0.55	0.45
	Load transfer capacity	0.43	0.57
	Line contact rate	0.46	0.54
Power supply capacity improvement degree		0.48	0.52
Distribution network operation index	line loss rate	0.52	0.48
	Voltage pass rate	0.47	0.53
	power distribution reliability	0.48	0.52
performance indicator	Electricity efficiency	0.50	0.50
	Energy conservation and emission reduction benefits	0.50	0.50
Customer satisfaction index		0.57	0.43

Solution, the subjective and objective weight is of relative importance, $\alpha = 0.496$, $\beta = 0.504$.

Applying the particle swarm algorithm to solve the proposed optimization model. The algorithm parameters are set as: the maximum iteration I is 100; maximum speed vmax=10; learning factor c1=c2=2; initial inertial weight wmax=0.8, final inertial weight wmin=0.3; population size N=30. The particle swarm algorithm was used to derive the optimal weights, as shown in Table 7 below.

Table 7. Optimal weight calculation results of each index.

Target system		Optimal weight
Grid improvement of the degree	N-1 criterion satisfaction rate	0.08
	Load transfer capacity	0.07
	Line contact rate	0.07
Power supply capacity improvement degree		0.13
Distribution network operation index	line loss rate	0.13
	Voltage pass rate	0.10
	power distribution reliability	0.12
performance indicator	Electricity efficiency	0.09
	Energy conservation and emission reduction benefits	0.07
Customer satisfaction index		0.14

Table 7 above calculates the optimal weight of each index, and the comprehensive contribution of each distribution network reserve project can be obtained by using the optimal weight coefficient of the contribution degree of each index and the contribution value of each index obtained by the combined weighting method based on the moment estimation theory.

Therefore, the contribution degree of the reserve items under the unit funds should be calculated. The results are shown in Table 8:

Table 8. Contribution degree of each reserve project in the unit investment.

project	A project	B project	C project
Comprehensive contribution degree of reserve projects	0.273	0.410	0.327
Total investment of the reserve project (ten thousand yuan)	185	218	207
Investment contribution degree of the reserve project unit	0.00148	0.00188	0.00157

As can be seen from the above table 8, the unit investment contribution of each reserve project is:0.00148,0.00188, and 0.00157, because the construction sequence of the three reserve projects is: Project B, Project C and project A.

5. Conclusion

Based on the characteristics and functions of the construction of distribution network production technology transformation projects, this paper constructs a reasonable evaluation index system, applies the method of combining subjective and objective weights to determine the index weights, and comprehensively considers the efficiency of project investment capital utilization and the contribution of project production to the development of the power grid, and calculates the comprehensive evaluation score of reserve projects, which is the final basis for the optimal ranking of reserve projects. This method and technology, the index weight calculation is reasonable, and the consideration dimension is more comprehensive, which can further improve the investment efficiency and efficiency of power grid production technology transformation projects.

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