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Risk assessment of development zone power grid investment

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Abstract. The new power reform policy proposes an orderly liberalization of the incremental power distribution business, which has brought many impacts on the power grid investment work of the power company, which is reflected in investment focus, investment efficiency and investment risk. This paper analyzes the uncertainty of power company's investment in power grid in the market environment, and uses the probability distribution method to model the influencing factors, and analyze the income of grid investment, evaluate the risk of grid investment, and establish grid investment. Multi-objective optimization function. Finally, an example is verified in Anhui Tongling Development Zone, which proves the validity and superiority of the model.

1. Introduction

With the deepening and development of the power system reform, it has brought many influences on the investment of power companies. In the context of the new power reform, the investment efficiency evaluation of the development zone power grid has gradually been valued by investors and managers. The investment park power grid will have huge policy risks and benefit risks [1, 2]. For the research in the grid investment process, the literature [3,4] has made in-depth research from the aspects of grid economic operation, grid investment planning, investment risk assessment, and safety evaluation. At present, China's power grid investment benefit evaluation mainly evaluates and selects evaluation indicators from the economic point of view, and focuses on the evaluation of investment benefits for single power grid construction projects [5,6], and lacks the evaluating overall benefits of power grid investment at the macro level [7].

For the risk analysis of grid investment, the most commonly used is the break-even method and sensitivity analysis [8]. Although it can show the degree of influence of various uncertain factors on the evaluation index, it does not take into account the random variation of uncertain factors. There are problems in the application, so there are certain limitations. Literature [9,10] introduces set pair analysis theory to deal with the uncertainty factors in power grid planning, and establishes a flexible grid planning model based on set pair analysis and multi-objectives, so that the economics and reliability of the optimization scheme can reach the most comprehensive benefits. good. In the actual investment activities, the change law of the uncertain factors affecting the economic effects of investment projects can often be described by probability distribution. Therefore, the economic effect of investment projects must also be a random variable, so the probability and statistics method is more suitable for the evaluation of grid investment projects. In the existing research using probability and statistics method, only the uncertainty of electricity sales or electricity purchase price is considered [11].

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The existing research focuses on the technical analysis and investment benefit evaluation of distribution network planning, and does not study the investment risk of new power reform. This paper analyzes the impact of the expansion of the distribution investment business on the investment of power grid enterprises. Taking into account the market factors, combined with a provincial incremental pilot case for risk assessment analysis, finally put forward relevant countermeasures and recommendations for grid enterprise distribution network planning and investment.

2. Income analysis of grid investment

The main uncertainties affecting the investment income of power grids in the development zone include power sales, power supply costs, line loss rate, average electricity price, purchase price and power supply reliability. In view of these factors, this paper uses a combination of improved incremental investment and probability statistics to assess the investment risk of the development zone grid. By quantifying the uncertainty of economic indicators by probability and statistics, the expectation and variance of uncertain factors are obtained. To quantify the investment risk of incremental distribution networks. Investing in the incremental distribution area, only the benefit analysis of the newly added assets, that is, the difference between the investment expenditure and the income of the incremental part is taken as the income of the investment. The annual total investment income of incremental power distribution is set as π. Among them, the income from electricity sales and electricity price will be increased as external investment income π_{external}, and the income from the increase of line loss rate and reliability rate will be reduced as internal investment income π_{internal}.

$$\pi = \pi_{\text{internal}} + \pi_{\text{external}} - C \tag{1}$$

$$\max \prod = E(\pi) = \sum_{s=1}^{N^s} \Pr^s \cdot \pi^s \tag{2}$$

Where π_{internal} is the internal income of the power company; π_{external} is the external income of the power company; C is the operating cost; $E()$ indicates the expected value of the aggregator's income in multiple scenarios; $\Pr^s$ indicates the probability of occurrence of the scenario s.

2.1. External income

The external income of the power company includes the increase in sales and electricity prices, expressed as:

$$\pi_{\text{external}} = (\lambda_1 - \frac{\lambda_2}{1-\alpha}) \times \Delta Q \tag{3}$$

Where λ_1 is the average electricity price of the power company; λ_2 is the average electricity price of the power company; α is the line loss rate; ΔQ is the increase in electricity sold by the power company.

The electricity sales, average electricity price and electricity price are all randomly simulated by Monte Carlo method, and the normal distribution is obtained. Taking the electricity price as an example, the mathematical expectation and variance can be expressed as:

$$E(\lambda_1) = \int_{-\infty}^{+\infty} \lambda_1 f(\lambda_1) d(\lambda_1) \tag{4}$$

$$D(\lambda_1) = \int_{-\infty}^{+\infty} [\lambda_1 - E(\lambda_1)]^2 f(\lambda_1) d(\lambda_1) \tag{5}$$

2.2. Internal income

The internal revenue of the power company includes the reduction of the line loss rate and the increase in the reliability rate, expressed as:

$$\pi_{internal} = [\eta \Delta\alpha\lambda_1 + \Delta w(\lambda_1 - \lambda_2)] \times \Delta Q \tag{6}$$

$$\eta = \begin{cases} 1 & ,\Delta\alpha \geq \alpha_1 \\ 0.8, & \Delta\alpha < \alpha_1 \end{cases} \tag{7}$$

Where $\Delta\alpha$ is the line loss rate reduced by the power company; η is the performance score; α_1 is the line loss standard; Δw is the increased power supply reliability.

Since the line loss rate is often a discrete random variable, the mathematical expectation and variance α can be expressed as:

$$E(\Delta\alpha) = \sum_{k=1}^{N^k} \Pr^k \cdot \Delta\alpha^k \tag{8}$$

$$D(\Delta\alpha) = \sum_{k=1}^{N^k} \Pr^k \cdot [\Delta\alpha^k - E(\Delta\alpha)]^2 \tag{9}$$

Where $\Delta\alpha^k$ is the k-th possible line loss rate of the power company project; P^k is the probability that the k-th item of the power company project may reduce the line loss rate.

3. Risk assessment of grid investment

3.1. CVaR risk model

The Conditional Value at Risk (CVaR) is a measure of market risk, defined as the maximum possible loss of the portfolio with a certain degree of confidence, expressed as:

$$VaR_\beta = \min\{l \in R : \Pr(L > l) \geq \beta\} = \min\{l \in R : \Psi_L(l) \geq \beta\} \tag{10}$$

Where VaR_β is the VaR value in the case where the confidence level is β; Ψ_L is the distribution function of the loss function L.

Since VaR only considers the risk threshold at a certain confidence level and does not take into account the investment risk value after exceeding the critical value, in addition, the method does not satisfy the sub-additive in the consistency risk measurement axiom system, not Consistency risk metrics.

In order to improve the VaR model, the concept of conditional risk value is proposed, defined as the VaR value above a given confidence level, and the average loss value of the portfolio is expressed as:

$$CVaR_\beta = \frac{1}{1-\beta}\int_\beta^1 VaR_u(L)du \tag{11}$$

This method not only considers the loss situation when the confidence threshold is exceeded, but also mitigates the possible impact on selecting a particular confidence level.

3.2. Grid company's revenue risk modeling

The CVaR model constructed in this paper is mainly used to describe the revenue risk of the grid company, so its objective function is the income function π of the grid company. The probability

density of the income function is shown in the figure. The red line segments in the figure respectively indicate the probability values corresponding to VaR and CVaR in the case where the confidence level is β, and VaR is the benefit value corresponding to the quantile $1-\beta$.

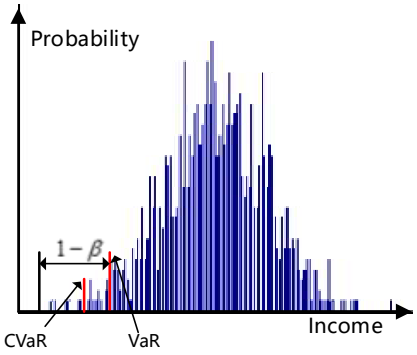


Figure 1. VaR and CVaR with a confidence level of β.

In this paper, the Monte Carlo scenario analysis method is used to establish the CVaR model of EVA net income risk, and the formula (11) is transformed into equations (12) and (13):

$$CVaR_\beta = \alpha_\beta - \frac{1}{1-\beta}\sum_{s=1}^{N^s} \Pr^s \times \delta^s \tag{12}$$

$$\delta^s = \begin{cases} \alpha_\beta - \pi^s, \pi^s \le \alpha_\beta \\ 0 \qquad\quad , \pi^s > \alpha_\beta \end{cases} \tag{13}$$

Where α_β is the VaR value of the income function at the confidence level is β; N^s is the total number of generated scenes; $\Pr^s$ is the probability of occurrence of the scene s; δ^s is the auxiliary variable representing the CVaR, indicating the positive difference of the current VaR value and the income of the scene s.

3.3. Multiple optimization

In this paper, the optimization target is the grid company's income and the conditional value of risk (CVaR). The objective function of the development zone grid investment can be expressed as:

$$\begin{cases} \max \Pi \\ \max CVaR_\beta \end{cases} \tag{14}$$

For the optimization problem of multi-objectives, this paper uses fuzzy satisfaction method to fuzzify each optimization target, and the linear satisfaction function is expressed as:

$$u(F) = \begin{cases} 0, & F \ge F^{\max} \\ \dfrac{F^{\max} - F}{F^{\max} - F^{\min}}, & F^{\min} < F < F^{\max} \\ 1, & F \le F^{\min} \end{cases} \tag{15}$$

Where $u(F)$ is the satisfaction degree of the objective function F; $F^{\max}$, $F^{\min}$ expressed the maximum value and the minimum value of the objective function respectively, F may be Π or $CVaR_\beta$ in the above formula.

Therefore, the above formula can be expressed as equation (16):

$$\min \rho = k_1 u(\Pi) + k_2 u(CVaR_\beta) \tag{16}$$

Where k_1 , k_2 is the weights of the satisfactions of the objective function Π , $CVaR_\beta$ respectively.

The constraint is as follows;

$$\begin{cases} u(\Pi) \geq u(\Pi)^{\min} \\ u(CVaR_\beta) \geq u(CVaR_\beta)^{\min} \end{cases} \tag{17}$$

Where $u(\Pi)^{\min}$, $u(CVaR_\beta)^{\min}$ is the satisfactory lower limit value of the objective function Π , $CVaR_\beta$ respectively.

4. Model solution

The solution of the model includes the prediction of the future scenario by the grid company, the simulation of the investment in the power grid of the development zone, the expected return and risk assessment, and the determination of the final investment project. Compared with the optimization algorithms such as genetic algorithm and simulated annealing algorithm, the harmony search algorithm is more suitable for such optimization problems with combinational properties. Therefore, the harmony search algorithm is used to determine the optimal combination of power grid companies' investment projects in the development zone.

The solution process of the grid company's participation in the development zone grid investment risk assessment model based on the market environment proposed in this paper, the specific steps include:

a) Initialize the harmony search memory HM to generate a combination of a plurality of items to be invested.

b) Using Monte Carlo simulation to generate a process for simulating the power grid investment in the development zone for various market scenarios in the future, and combining the cost-benefit function to solve the return value under different scenarios.

c) After obtaining the return value in all scenarios, the expected value and the conditional risk return CVaR value are solved, and the comprehensive satisfaction degree is calculated by combining the multi-objective optimization model in the previous section.

d) Determine the optimal portfolio of investment projects and report them by traversing the overall satisfaction of each instrument and updating the solution in HM. The specific solution flow is shown in the figure:

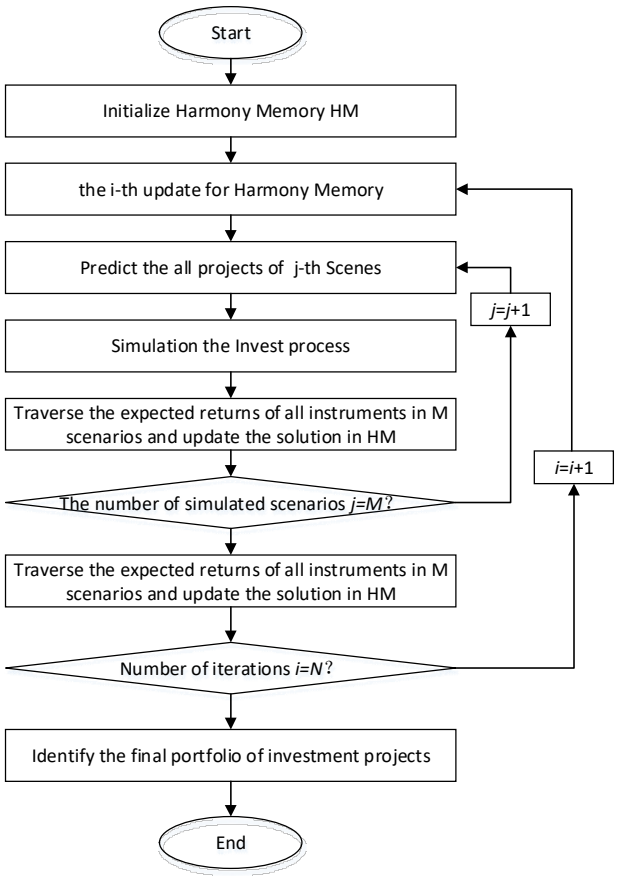


Figure 2. Flow chart of the algorithm.

5. Case studies

This paper analyzes the risk of power grid investment in an economic development zone in Tongling, Anhui Province. The project is basically a power grid construction with completely added blank areas. The original power supply reliability in the region is 90%, the line loss rate is 10%, and the confidence level of risk prediction is 90%. Assume that the investment funds are all from the grid company. The project bank to be invested includes the following three projects. The projects to be invested mainly affect the power sales, power supply reliability and line loss rate of the future power grid. The specific distribution is as follows:

Table 1. Project library to be invested.

Numble	Operating costs (M$)	Increase sales(GWh)	Reduce line loss (%)	power reliability increase(%)
A	16	$N(98,2^2)$	$N(3,0.1^2)$	$N(3,0.1^2)$
B	22	$N(110,3^2)$	$N(6,0.1^2)$	$N(7,0.1^2)$
C	20	$N(108,2^2)$	$N(5,0.1^2)$	$N(5,0.1^2)$

In addition to factors such as power sales, power supply reliability and line loss rate, the price of electricity sold and the price of electricity purchased as uncertainties in the market environment will also have an impact on the profitability of the power company. This paper assumes that its distribution is as shown in the table below:

Table 2. Electricity price parameter distribution.

Factors	Predicted distribution
Electricity price($/kWh)	$N(0.5,0.01^2)$
Purchase price($/kWh)	$N(0.3, 0.01^2)$

In this paper, Monte Carlo simulation method is used to generate various scenarios for future power grid development based on uncertain factors, and the portfolio economics and risk assessment of each project to be invested is proposed through the proposed risk assessment method, and the expected returns and risks of each project group are obtained. The benefits and satisfaction are shown in the table below.

Table 3. Project's income indicator.

Numble	Expected return ($)	CVaR($)	Satisfaction (p.u.)
A	3459700	825100	1
B	3468800	213900	1.96
C	3695700	786200	0.0636

It can be seen that the expected return and online income of investment project C are at a relatively high level, and the satisfaction is the smallest, which is the optimal investment plan. Although the expected return value of Project B is larger than Project A, its revenue risk is relatively large due to the uncertainty of its electricity sales. Its online income is only 21,900$, which is 26% of Project A. The income function graph of item C is as follows.

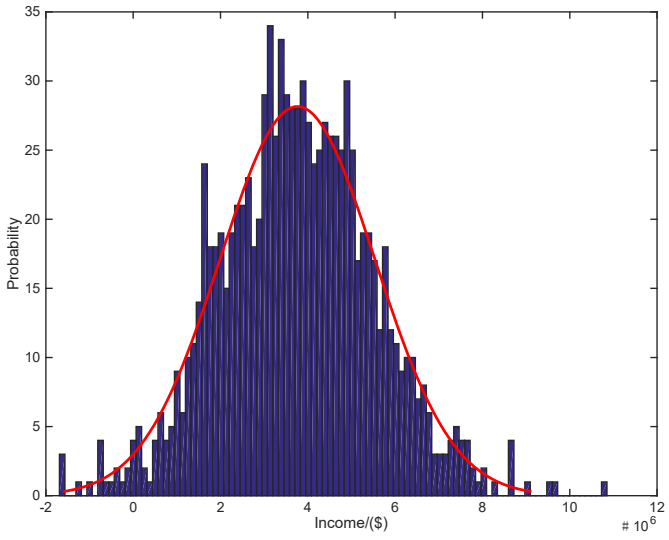


Figure 3. Income function project C

It can be seen that the income function of Project C is relatively stable, basically close to its expected return value, but even so, in extreme cases, investment project C may still have negative returns, and the CVaR model in this paper effectively reflects The tail risk of the income function proves the superiority and effectiveness of the model.

Because the risk of project B is relatively high, this paper predicts the risk of project B by changing the confidence. The confidence is 80%, 90% and 95% respectively. The results are shown in the figure.

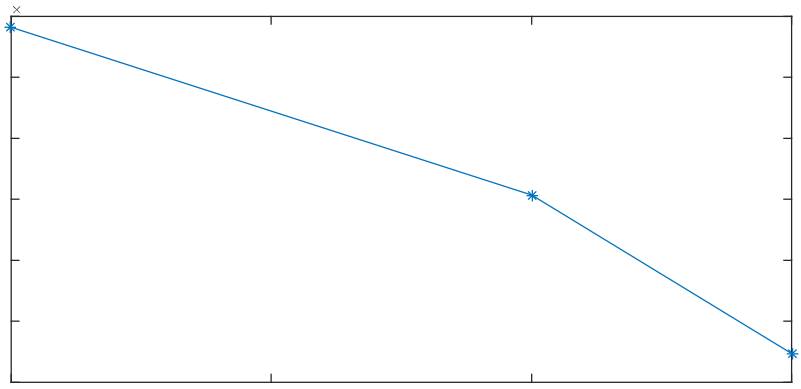


Figure 4. Project's income and CVaR.

It can be seen that in the case of a 95% confidence level, the project's revenue is negative, and increasing confidence can better assess the economic risk of the investment project.

6. Conclusion

This paper analyzes the uncertainty of power companies' investment in power grids in the market environment, and uses the probability distribution method to model the influencing factors, analyzes the revenue of grid investment, and uses CVaR model to evaluate the risk of grid investment, and establish a multi-objective optimization function for grid investment. It is exemplified that the CVaR risk assessment model can effectively assess the risk of grid investment, and increasing confidence can improve the conservativeness of investment strategies.

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