

Risk analysis of power plant investment based on Monte Carlo

Dongxiao Niu, Jingpeng Qiu, Meiqiong Wu and Yali Huang

School of North China Electric Power University, Beijing 102206, China

Abstract. With the increase of demand for electric power supply, power plant investment is rising. However huge investment usually causes more risks. Based on the market environment of a power plant, combined with cogeneration investment situation in China, the regional electric power demand and supply situation and characteristics of the power grid, the investment risk is evaluated and predicted from natural risk, social risk, political risk, economic risk, technical risk and other risk. Risk analysis model has been built based on Monte Carlo, and the calculation results shows relatively accurate, so this model has a certain guiding significance for the managers.

Keywords: Power Plant; Investment; Risk; Monte Carlo.

1. Introduction

The competition is increasing in current power market, therefore many excellent power generation enterprises pay more and more attention to the research on the investment risk. New plant investment has certain risk, for instance new plant needs high capital investment, whether the production technology can meet the design requirements after putting into operation, how much profit can be achieved and whether the profit can make up for the previous assets investment, these risks are pre-plant should be fully taken into account. Therefore, the in-depth analysis of the power plant investment risk, not only has research significance in technical aspects, but also has practical significance in development of the power plant.

2. Monte Carlo Simulation

2.1 Basic Modeling Method

The application of Monte Carlo simulation in the investment risk is getting the probability distribution of the cost factors and value range through investigation, then summing the sample values in order to obtain a grid project construction cost. The formula is:

$$Y = \sum_{i=1}^n X_i \quad (1)$$

Y means total construction cost, and X means cost factors.

In the same way, a number of data Y_i can be get by times independent sampling. When the sampling times are enough to make the frequency approximation equal to the probability, the probability distribution and digital features of the grid engineering cost can be obtained.

2.2 Procedures of Monte Carlo

The Monte Carlo simulation steps are as follows in the determination of power grid project cost.

(1) Getting the probability distribution of the cost factors through investigation.

(2) Sampling randomly in the estimated range of cost factors, and obtaining the total cost of the project according to the sum of the sample results.

(3) Repeating step2 10,000 times, then analyzing the simulation results of 10,000 project costs. Generally, you can get actual situation of probability distribution and characteristics of digital by 4,000 times simulation, thus 10,000 times will make data analysis more accurate.

2.3 Determination of Probability Distribution

The probability distribution of each cost varies with the specific condition of each project. For an electric grid project, it's a very complicated work to analyze the probability distribution of each cost according to previous data. Fortunately study carried by Stephen Grey found that triangular distribution can be used to replace variable probability distribution, which makes the data processing greatly simplified, and the loss of information is lesser, so the results are closer to the real situation. Therefore, if we can determine the most probable, minimum and maximum cost according to the past

experience and the existing information, then the most likely, the minimum and the maximum cost, the corresponding probability, expectation and variance of the whole project cost can be obtained by Monte Carlo simulation.

3. Investment Risk Model Construction

Considering the dynamic change of variables, we can get different values by other means, but the result is only a range, and unable to measure its reliability. The actual problem is more complex, if you want to get all the results, you must analyze all the combinations of input variables, and get numerous output, so the conventional method is difficult to realize. Nevertheless, Monte Carlo simulation overcomes this limitation. Multiple risk variables can be simultaneously input into this model, the probability distribution of the input variable is used instead of the single value, and the results of the objective function are simulated by the probability distribution. Meanwhile, the sensitivity of the objective function for each variable will be obtained.

3.1 Technical and Economic Parameters of Power Plant

Annual utilization hours: 5600 h

Coal price (including freight): Standard coal 450 yuan/t

Personnel quota: 210 people

Annual average wage: 50000yuan/person, the welfare is 14% of the wages.

Service life: 20 years

Maintenance material cost: 5 yuan/MWh

Other expense: 10 yuan/MWh

Electricity price (excluding tax): 0.32 yuan/kWh

Heat price (excluding tax): 20 yuan/GJ

Basic return rate: 8%

According to documents, generating VAT rate is 17%, heating VAT rate is 13%, education additional tax rate is 4%, urban maintenance and construction tax rate is 5%, and the income tax rate is 33%.

3.2 Monte Carlo Risk analysis Model Construction

In order to analyze the economic effects of the technological transformation, we set the target of risk assessment to the annual profit after tax Y , and Y complies with the following formula:

$$\text{Profit after tax } Y = \text{product sales revenue } X_1 - \text{taxes and additional } X_2 - \text{total cost } X_3 - \text{income tax } X_4 \quad (2)$$

$$\text{Product sales revenue } X_1 = \text{heating revenue } R_1 + \text{generating revenue } R_2 \quad (3)$$

$$\text{Taxes and additional } X_2 = \text{output VAT} - \text{input VAT} + \text{education additional tax} + \text{urban maintenance and construction tax} \quad (4)$$

$$\text{Output VAT} = \text{generating revenue} \times \text{generating VAT rate} + \text{heating revenue} \times \text{heating VAT rate} \quad (5)$$

$$\text{Input VAT} = \text{fuel cost} \times \text{fuel rate} \quad (6)$$

$$\text{Urban maintenance and construction tax} = (\text{output VAT} - \text{input VAT} + \text{sales tax} + \text{consumption tax}) \times \text{urban maintenance and construction tax rate} \quad (7)$$

$$\text{Education additional tax} = (\text{output VAT} - \text{input VAT}) \times \text{education additional tax rate} \quad (8)$$

$$\text{Total cost} = \text{fuel cost} + \text{depreciation cost} + \text{repair cost} + \text{salary and benefit} + \text{material cost} + \text{other expense} \quad (9)$$

$$\text{Incoming tax} = (\text{product sales revenue } X_1 - \text{taxes and additional } X_2 - \text{total cost } X_3) \times \text{incoming tax rate} \quad (10)$$

1) The impact of natural risks on the economic benefits is relatively simple. Generally, harsh natural environment will cause a certain impact on fuel purchase and transportation. Natural risks are set to T_1 .

2) Social risks need to take into account the market competition, the prospect of social demand and other risk factors. They primarily affect the heat supply and generation income. Social risks are set to T_2 .

3) Political risks mainly refer to changes in laws and regulations. In generally, this risk variable is relatively stable, but as the national emphasizes on environmental protection, and coal combustion will produce pollution gas, so the political risks will have an impact on fuel cost. Political risks are set to T_3 .

4) Economic risks of plant are more complex, affecting the changes of various tax rate, artificial price and especially fuel cost. Economic risks are set to T_4 .

5) Technical risks directly affect sales income. Advanced technology will produce more revenue, but simultaneously need to take a certain risk of high investment. Technical risks are set to T_5 .

6) Other risks affect a large range of product sales income and total costs, they mainly refer to the contract risks which are usually encountered in management and production. Other risks are set to T_6 .

After analyzing the influence of each risk on the investment, we determine the probability distribution of the risk variables by means of collecting historical data. It can be found that the triangular distribution can well demonstrates probability distribution, because it greatly reduces the workload and the results are close to the real situation.

According to the logical relationship between the above variables, the function model is shown in table 1. The reference value and effect coefficient are the data from similar plant.

Table 1 Function relationship between investment cost and risk factors

Cost	Risk factor	Reference value	Simulation value
Heating revenue	T_2, T_5, T_6	r_1	$Rr_1 = T_2 * T_5 * T_6 * r_1$
Generating revenue	T_2, T_5, T_6	r_2	$Rr_2 = T_2 * T_5 * T_6 * r_2$
Product sales revenue		$X_1 = r_1 + r_2$	$RX_1 = Rr_1 + Rr_2$
Fuel cost	T_1, T_3, T_4	C_1	$RC_1 = T_1 * T_3 * T_4 * C_1$
Output VAT		$r_3 = r_1 * K_1 + r_2 * K_2$	$Rr_3 = Rr_1 * K_1 + Rr_2 * K_2$
Input VAT		$r_4 = C_1 * K_3$	$Rr_4 = RC_1 * K_3$
Urban maintenance and construction tax		$r_5 = (r_3 - r_4) * K_4$	$Rr_5 = (Rr_3 - Rr_4) * K_4$
Education additional tax		$r_6 = (r_3 - r_4) * K_5$	$Rr_6 = (Rr_3 - Rr_4) * K_5$
Taxes and additional		$X_2 = r_3 - r_4 + r_5 + r_6$	$RX_2 = Rr_3 - Rr_4 + Rr_5 + Rr_6$
Depreciation cost		r_8	$Rr_8 = r_8$
Salary and benefit	T_4	C_2	$RC_2 = T_4 * C_2$
Other expense		r_9	$Rr_9 = r_9$
Material cost		r_{10}	$Rr_{10} = r_{10}$
Total cost		$X_3 = r_8 + C_2 + r_9 + r_{10}$	$RX_3 = Rr_8 + RC_2 + Rr_9 + Rr_{10}$
Incoming tax		$X_4 = (X_1 - X_2 - X_3) * K_6$	$RX_4 = (RX_1 - RX_2 - RX_3) * K_6$
Profit after tax		$Y = X_1 - X_2 - X_3 - X_4$	$RY = RX_1 - RX_2 - RX_3 - RX_4$

After determining the relationship between the risk variables, we set the times of Monte Carlo simulation, and then use Crystal Ball software to simulate and analyze, the results are obtain the probability distribution, expectations and standard deviation of the project investment benefit, and the sensitivity of the investment benefit to the various risk factors. The greater the sensitivity coefficient, the greater the degree of the impact of the risk to the benefit.

4. Case Analysis

Coefficient of risk variable to cost is shown in table 2. The reference values of each cost refer to similar projects, and the minimum, maximum and most probable effect coefficient are determined by historical experience and differences caused by information estimation.

Table 2 Coefficient of risk variable to cost

Risk variable	Effect variable	Effect coefficient		
		minimum	Most probable	maximum
T1	Fuel cost	0.90	1.2	1.3
T2	Heating &Generating revenue	0.93	1.0	1.1
T3	Fuel cost	0.92	1.1	1.15
T4	Rate,Fuel cost ,Benefit	0.93	1.02	1.2
T5	Sales revenue	0.95	1.05	1.22
T6	Sales revenue & Total cost	0.96	1.1	1.18

Entering the model and the parameters into software, Monte Carlo simulation is set up for 10000 times, and the results are shown in Fig 1. As can be seen from the figure, under the combined effect of many risks, the annual investment return is range 181.8093 to 211.0264 million yuan after technologic transformation, the expectation is 196.8011 million yuan, and the standard deviation is 452.44. The probability of simulation data is 53.75%, falling range 193.8345 to 200.5811 million yuan. In conclusion the investment return is much better, under normal production conditions, the return can be about 8.164 million yuan.

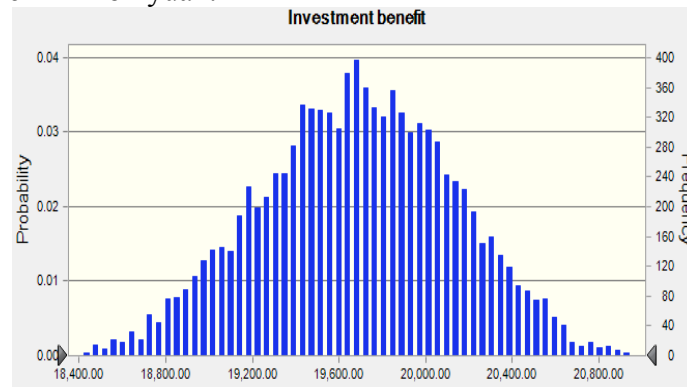


Fig 1 Monte Carlo simulation results

The sequence of various risk factors impact on investment benefit is revealed in figure 2. It shows that investment return is most sensitive to economic risk, secondly to technical risk, which indicates the revenue is greatly affected by market demand and price. The sensitivity of social risk is relatively close to that of political risk.

In setting conditions of this paper, natural conditions change is small, so is the impact on the benefits. However, in some areas where natural condition is harsh, fuel such as coal is often restricted by the environment, in this case, the natural risk will greatly impact on power plant benefits.

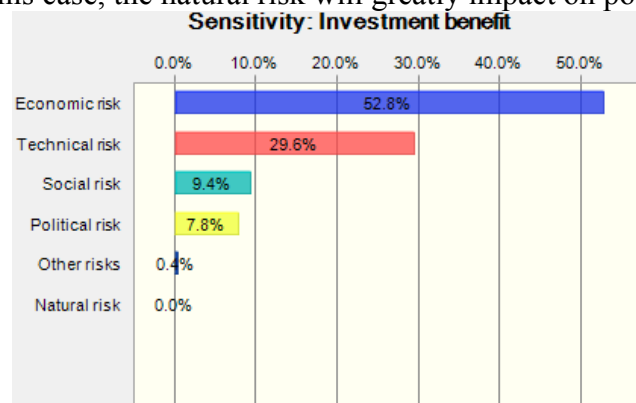


Fig 2 Risk factor sensitivity analysis

5. Conclusion

Based on the market environment of a power plant, we study the investment risks of plant. Firstly, based on the basic theory of the plant investment risk, combined the characteristics of the power construction projects, we consider all sorts of risks encountered in the process of construction and

production, such as natural, social, political, economic, technical and other risks. And then we determine the main risk factors affecting the investment, in addition, making qualitative and quantitative research of these risk factors. Finally, the investment risk is evaluated and predicted by Monte Carlo simulation.

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