Asia Pacific Science Press

Journal of Advances in Engineering and Technology
ISSN(O): 3005-7507
ISSN(P): 3005-7493
https://doi.org/10.62177/jaet.v1i1.18

Optimization and Demonstration of PV Power Plant Investment Evaluation and Decision Model under the Background of Marketization

Cao Chen [1 *]

[1] School of Electrical Engineering, Zhejiang University, Zhejiang, Hangzhou 310058, China

[*]Corresponding author: Cao Chen

Abstract: Based on the real option analysis method, this paper makes an empirical analysis of the evaluation and optimization of the model, and analyzes the main factors of the investment value of photovoltaic power plants in combination with the investment decision-making characteristics of photovoltaic power plant projects under the background of marketization. The electricity price and generation income, transaction price and income are all processed by geometric Brownian motion, and the random process is obtained by Monte Carlo simulation method. Based on the sensitivity analysis of the uncertain factors of the model, the investment risk of photovoltaic power station is evaluated and the suggestions are put forward. The results show that when the on-grid electricity price increases by 10%, the net present value is about 6 million yuan in the 26th year. Therefore, how to evaluate the uncertainty factors of photovoltaic power plant investment and make scientific and reasonable investment decisions is of great significance for the development of photovoltaic power generation.

Keywords: Photovoltaic Power Plant; Investment Evaluation and Decision-making Model; Real Option Analysis; Geometric Brownian Motion; Sensitivity Analysis

---

Published: July 31, 2024

Introduction

Photovoltaic power generation is characterized by clean and renewable energy and short construction period. Photovoltaic power generation technology has a good application prospect because of its renewable technology, carbon emission reduction and environmental footprint[1]. The investment of photovoltaic power plant project requires a large amount of construction cost, accompanied by a long payback period of investment capital. Choosing the right time for project investment can reduce the capital cost and improve the project income [2]. However, the traditional investment decision-making model can not reflect its uncertainty well. Therefore, it is necessary to optimize the evaluation decision-making model so that it can not only identify the best investment opportunity of photovoltaic power plant project, but also evaluate the investment value of reasonable investment period [3]. The research and optimization of investment evaluation and decision-making of photovoltaic power plants can provide investors with new analysis perspectives and dynamic investment decision-making methods [4]. Under the background of marketization, investors can use the option of investment projects endowed by real options to reduce the impact of uncertainty and make more scientific and reasonable investment decisions.

This paper constructs a model optimization framework, makes an empirical analysis of the model based on the real option analysis method, and comprehensively considers various risk factors that may exist in the photovoltaic power plant, and evaluates its risk. Through the analysis and prediction of the value of investment decisions, the best time point for investment is selected. Finally, combined with the sensitivity analysis of the uncertain factors of photovoltaic power plant, the scientificity and practicability of the investment evaluation and decision-making model of photovoltaic power plant under the market environment are verified.

1. Construction of Investment Evaluation and Decision-making Model for Photovoltaic Power Plant

Under the background of marketization, in order to effectively evaluate the investment of photovoltaic power station, a mathematical model of investment evaluation and decision-making of photovoltaic power station is established. Considerations include the cost of photovoltaic systems, power generation efficiency, operation and maintenance costs, feed-in tariffs, government policies and potential risks. The model aims to quantify these factors and make investment decisions based on them.

Considering the above factors, the mathematical expression of the investment evaluation and decision-making model of photovoltaic power plant is as follows:

$$NPV = \sum_{t=0}^{T} \frac{R_t - C_{pv} - C_{om}}{\left(1+r\right)^t} + S - \sum_{i=1}^{n} RF_i \cdot R_i \tag{1}$$

$$IRR : NPV = 0 \tag{2}$$

Where T is the economic life year of the investment project and r is the discount rate, indicating the time value of capital. n Is the number of risk factors, RF_i is the weight of the risk factors i , R_t is t the total return of the year. By setting appropriate parameter values, the use model can be used to evaluate the investment of photovoltaic power plants, while considering the cost, benefit, policy and potential risks and other factors to support the formulation of investment decisions.

2. Investment Evaluation and Optimization Objective

In the investment evaluation and decision-making model of photovoltaic power plant, the use of financial analysis and real options and other methods can affect the decision-making factors and returns[5]of investment. Investment evaluation and decision-making means that investors use reasonable scientific means and some methods to evaluate and demonstrate the scheme, so as to select the most satisfactory investment evaluation and decision-making scheme. Photovoltaic power plant investment evaluation and decision-making model optimization framework provides appropriate investment evaluation and decision-making for photovoltaic power plant, which can realize the large-scale development of photovoltaic capacity, thus bringing certain improvement to the social environment and economic benefits. Despite the high initial investment[6]requirements of photovoltaic power plants, with the continuous development of the current society, photovoltaic technology has achieved good results in reducing pollution and greenhouse gas emissions, which is conducive to coping with the rising climate and environmental protection issues. The large-scale and rapid development of photovoltaic power plants will promote the development of other industries, which will lead to the emergence of more employment opportunities, while technological innovation will also reduce its cost, obtain higher return on investment, and bring social and economic benefits.[7]

In photovoltaic power plant projects, decision-makers can make decisions that are beneficial to enterprises according to the situation, that is, the flexibility[8]of management. According to the capital budget and investment analysis, decision-makers have the power and ability to constantly revise the investment plan, change the original investment, construction and operation strategy, and obtain maximum profits in the uncertain future market. Investment in[9]photovoltaic power plant projects does not belong to the type of projects that either invest now or never invest, and investors often have more room for manoeuvre in investment timing. This project-specific flexibility represents an option behavior, usually the higher the degree of freedom of the investment decision-maker, the higher the value of the investment project.

3. An Optimal Decision Model Base on Real Option Analysis

The real option analysis method generally includes three models or methods to solve the problem. The basis of investment decision-making based on the real option method is to predict and analyze the value of the photovoltaic power plant project reasonably, and then identify the best time for project investment on this basis. In this paper, the value of the photovoltaic power plant project is divided into three main components, the generation income of the photovoltaic power plant, the carbon trading income of photovoltaic power plant, and the project cost of photovoltaic power station.

It is assumed that the initial annual electricity price revenue is S_T , α is the drift parameter, that is, the annual growth rate, σ which is a measure of volatility, α σ and the values of and are used to predict the annual volatility of non-renewable energy prices. The annual growth rate α can be obtained from the expected value of the past growth rate.

The price change of renewable energy is closely related to the price change of non-renewable energy, and when the price of non-renewable energy is increasing, renewable energy becomes more attractive. However, the uncertainty and volatility of non-renewable energy prices have a negative impact on the development of non-renewable energy. When the price of non-renewable energy is lower than the price of renewable energy, when the cost of non-renewable energy power plants is correspondingly lower, although the high price of non-renewables makes renewable energy competitive, the relatively higher investment cost of non-renewables power generation projects makes it less attractive. Therefore, σ the value of can also be calculated by the value of non-renewable energy price volatility in the past H years, and the volatility of the past growth rate is:

$$\sigma = \sqrt{\left(\frac{1}{\mathrm{h}}-1\right)\sum_{t=1}^{l}\left(\mu_t - \bar{u}\right)^2} \,/\, \sqrt{\Delta t} \tag{3}$$

According to the length Δt of the validity period t of the time option, one month or one twelfth of a year is decomposed into $t/\Delta t$ time intervals. Assuming that the initial electricity price is S_0 , at the beginning of the first stage, The price of electricity S_0 may be increased to uS_0 at the end of the period according to the probability p . According to the complementary probability $1-p$ dS_0 , the sum d represents the continuous compound interest or logarithmic rate of return, respectively, for the increase or decrease u of electricity price, and $d=1/u$. Among them $0<1<p$, $0<1-p<1$. The u, d, p value of is determined by the following formula:

$$p = \frac{e^{\alpha \Delta t} - d}{u - d}, d = e^{-\sigma\sqrt{\Delta t}}, u = e^{\sigma\sqrt{\Delta t}} \tag{4}$$

The validity period t of the option is divided into j two equal sub-intervals, and the electricity price jumps k up times and falls down $j-k$ times to reach the price $S_0 u^k d^{j-k}$ in N the period. Since the successive steps of the random walk of the electricity price are independent of each other, the cumulative variation follows a binomial distribution.

The electricity price of photovoltaic power plant project conforms to geometric Brownian motion and satisfies Markov property, which can also be called Markov process. Because the steps n of the random walk will tend to infinity for any finite time t, the binomial distribution will converge to a normal distribution, that is, $\frac{dS_T}{S_T}$ follow the normal distribution. The S_T absolute change dS_T in follows a lognormal distribution, usually of the form:

$$dS_T = \alpha S_T dt + \sigma S_T \, dZ_t \tag{5}$$

Where, $Z_t = \varepsilon_t \sqrt{\Delta dt}$, dZ_t is a Wiener process, then $In\left[\frac{dS_T}{S_T}\right] \in N(u, \sigma)$ the expected value of, S_T is $S_0 e^{\alpha T}$, and the variance is $S_0{}^2 e^{2\alpha T}\left(e^{\sigma^2 T} - 1\right)$.

If the power generation is assumed to be stable, the price revenue, as the constant multiplier of the electricity price, also obeys the geometric Brownian motion with the same parameter α σ as. When Monte Carlo is used to simulate the path, the random path of the price is similar to the path of the generation revenue.

According to the established investment evaluation and decision-making model, assuming that the construction period of the photovoltaic power station project is T_C and the operation period is T_E , the total life cycle of the project is $T_C + T_E$. It is assumed that the total annual income of the photovoltaic power plant project is R , R_T which is the income of the year, of which S_T is the income of power generation and R_T carbon trading. It is assumed that S_T the random paths of and R_T conform to the mathematical characteristics of geometric Brownian motion, that is,

$$V_T = (1-\theta)\left(S_T + R_T\right) - C_t \cdot Q = (1-\theta)S_T + (1-\theta)R_T - C_t \cdot Q \tag{6}$$

Where, θ is the tax rate of various taxes and surcharges, and the power generation cost per unit of electricity is C_t, then the total cost is $C_t \cdot Q$.

Assuming that the duration of deferred investment is t, the project value is:

$$\Phi(t) = \sum_{T_C+1+t}^{T_C+T_E+t} S_T \cdot e^{-\alpha T} + \sum_{T_C+1+t}^{T_C+T_E+t} R_T \cdot e^{-\alpha' T} - C_t \cdot Q \tag{7}$$

Maximize the $\Phi\left(t\right)$ value of, that $\max \Phi\left(t\right)$ is t, the value of is the best time to invest.

4. Empirical Analysis of Investment Evaluation and Decision-making Optimization Model for Photovoltaic Power Plant

4.1 Empirical Background

In order to effectively optimize the model and verify its practicability, an Agent-Based Modeling (ABM) platform is selected to test the model, which can simulate market changes, policy evolution, technological innovation and other scenarios, so as to comprehensively evaluate the response ability of the model. The real-time, dynamic and scalable simulation platform can better simulate the operating environment of photovoltaic power plants in the real world and provide a more reliable experimental basis. In addition, the data set in the experiment also includes the electricity price under various market conditions, the actual power generation data of photovoltaic power plants, and the impact of policy changes on the return on investment. Historical data can be used to validate the model's responsiveness to market volatility and policy changes, while real-time data can provide more accurate insights into the current market environment.

4.2 Risk Score of PV Power Plant

This paper selects a number of large-scale photovoltaic power plants as a reference to make an empirical analysis of the case of investment evaluation and decision-making. According to the photovoltaic power station data obtained by ABM platform, experts in relevant fields are invited to score the risks from the risk levels of policy, economy, market, technology, nature and operation according to the scoring method. The types of power stations are shown in Table 1.

Table 1 Power Station Type

Power Station	Type	Description
A	Ordinary commercial use photovoltaic power station	Moderate policy and economic risk, suitable for general commercial use
B	Economical photovoltaic power station	In the case of higher economic risks, greater economic benefits can be obtained through higher market risks.
C	Large-scale photovoltaic power plants with high market risk	The market risk and technical risk are high, and it may be a large-scale commercial project.
D	Technology-leading photovoltaic power station	Technical risk is relatively high, and new technology or equipment may be adopted
E	Small commercial photovoltaic power plant	It is suitable for small-scale commercial investment with low economic risk.
F	Photovoltaic power station for commercial use	Medium-sized commercial projects face certain market and technical risks.
G	Large-scale commercial photovoltaic power station	Commercial projects with large scale and high market and operation risks
H	High-risk photovoltaic	Higher market risk and operational risk may require more prudent investment

	power plant	consideration

Table 2 shows the risk scoring results of photovoltaic power plants, in which the score of policy risk is the lowest, and the scores of market risk and operational risk are higher, with the highest score of 1.1. Power Station B and Power Station D have the highest scores in terms of economic risk, which are 0.7 respectively, indicating that they have relatively greater risks in the face of economic fluctuations. Generally, due to the high investment risk of photovoltaic power generation and the need for more professional knowledge, it is necessary to make a comprehensive and detailed assessment of the risk, stability, economy, feasibility and practicability of the investment evaluation and decision-making of photovoltaic power plants, and to use scientific investment evaluation methods and quote original data models to reduce the investment risk of photovoltaic power plants. To ensure that the investment evaluation can achieve the expected return target.

Table 2 Risk Scoring Results of Photovoltaic Power Plant

Power Station	Policy risk	Economic risk	Market risk	Technical risk	Natural risks	Operational risk
A	0.5	0.5	0.7	0.7	0.5	0.9
B	0.3	0.7	0.9	0.7	0.3	0.7
C	0.5	0.5	1.1	0.5	0.5	1.1
D	0.3	0.7	0.9	0.9	0.7	0.7
E	0.5	0.3	0.9	0.5	0.3	0.7
F	0.5	0.5	0.7	0.3	0.3	0.7
G	0.5	0.5	0.9	0.7	0.5	0.9
H	0.3	0.7	1.1	0.5	0.5	0.5

Sensitivity analysis is an analysis method for project evaluation and research. When a value changes, the trajectory of the model changes, which is a sensitive parameter, otherwise it is a non-sensitive parameter. Based on the pre-test analysis, the sensitivity analysis of the purchase cost of power generation equipment and electricity price of photovoltaic power station is carried out. As the investment in photovoltaic power plants is mainly to purchase basic equipment for power generation, the purchase cost is adjusted to increase or decrease by 10%. The change of NPV is observed and its sensitivity is analyzed. According to the sensitivity analysis of equipment purchase cost, when the purchase cost is increased by 10%, the net present value is about 2.19 million yuan in the 26th year. When the purchasing cost is reduced by 10%, the net present value is about 5 million yuan in the 26th year.

Under the background of marketization, the main revenue mode of photovoltaic power plants is to sell electricity, which is the product of electricity price and lighting. Therefore, the electricity price is an important factor affecting the investment evaluation and decision-making of photovoltaic power plants, and the electricity price adjustment is set to increase or decrease by 10%. Sensitivity of feed-in tariff, when the selling price is increased by 10%, the net present value is about 6 million yuan in the 26th year. When the electricity price is reduced by 10%, the net present value is about -1.6 million yuan in the 26th year. The advantages of energy saving and environmental protection of photovoltaic power generation make it receive strong social support, and China has issued a series of policies to support its future development. At present, photovoltaic power plants should not blindly invest in the construction of power generation projects, but should fully consider a series of risk factors before making investment evaluation decisions.

5. Conclusion

Based on the real option analysis method, this paper fully considers the price income brought by policy, market and technology changes, the uncertainty in the whole life cycle of power plants and the uncertainty of transaction income in a long period of time, as well as the flexibility of management decision-making itself. Firstly, the risk value of photovoltaic power plants is analyzed, in which the policy risk has the lowest score, while the market risk and operational risk have higher scores, up to 1.1. Then the sensitivity analysis of equipment purchase cost and on-grid electricity price is carried out. When the equipment purchase cost increases by 10%, the net present value is about 2.19 million yuan in the 26th year. When the on-grid electricity price increases by 10%, the net present value is about 6 million yuan in the 26th year. Therefore, the investment evaluation decision is a comprehensive and complex problem, and the optimization of the model should be carried out more carefully, in order to make more accurate investment and increase the effect of model optimization.

References

[1] Huang Xiaoyan, Wang Shaokang. Tax Risk Management in the Bidding Stage of "One Belt and One Road" EPC Project — Taking X Company's Investment in Vietnam Photovoltaic Power Plant as an Example[J]. International Taxation, 2021(5): 67-74.

[2] Pan Qike, Li Gensen, Chen Chunhua, Bai Baohua, Song Ning, Cheng Ronglan, Huang Xingwan. Analysis of Design Method for Rigid Pile Foundation of Photovoltaic Support[J]. Journal of Wuhan University: Engineering Science Edition, 2021, 54(S02): 207-210.

[3] Li Yong, Liu Peiyao, Hu Sijia, Lin Jinjie, Luo Longfu. Harmonic Resonance Suppression Method of Photovoltaic Power Station Based on Inductive Filtering[J]. Chinese Journal of Electrical Technology, 2022, 37(15): 3781-3793.

[4] Ye Lin, Cui Baodan, Li Zhuo, Zhao Yongning, Lu Peng. Combination Identification Method for High Proportion Abnormal Operation Data of Photovoltaic Power Station[J]. Automation of Electric Power Systems, 2022, 46(20): 74-82.

[5] Lu Mingfang, Li Xianshan, Li Fei, Xiong Wei, Cheng Shan. Bi-level Game Optimization Based Energy Storage Lease Allocation Strategy for PV Power

Station Cluster[J]. Proceedings of the CSEE, 2022, 42(16): 5887-5898.

[6] Chen Zhiyuan, Wang Tieli. Multi-agent Evolutionary Game and Simulation Research of Distributed Photovoltaic Promotion[J]. Journal of Chongqing University of Technology: Natural Science, 2022, 36(12): 297-304.

[7] Wen Subin, Gao Qi. Multi-tool Combination Decision-making of Photovoltaic Power Plant Investment Project[J]. Friends of Accounting, 2018(6): 4.

[8] Fan Xiaowei, Wang Ruimiao, Zhu Xiaojun, Yao Long, Zhou Xinghua, Zhang Xiao. Investment Decision of Distributed Photovoltaic Energy Storage Based on Improved Genetic Simulated Annealing Algorithm[J]. Renewable Energy, 2022, 40(11): 1539-1545.

[9] Du Zhihang, Qiu Shangqing. Research on Investment and Financial Evaluation Method of Parity Photovoltaic Project — Taking a 100MW Project in Guangdong Province as an Example[J]. Construction Economy, 2022, 43(S01): 370-371.