Economic Benefit Analysis of "Direct Trading Model" DPV Project—Real Options Method

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Abstract. With the continuous advancement of market-oriented transaction of distributed photovoltaic (DPV) power generation, the "direct trading model" (DTM) as the most important market-oriented transaction model occupies an increasingly important position, but the DTM economic benefits affected by many uncertainties, the real option method (ROV) can calculate the value of uncertainty factors, so this paper uses the ROV method to evaluate the value of the DPV projects. This paper first constructs the revenue and cost model, then introduces ROV theory to construct the value model with risk factors; secondly, through empirical analysis, it proves that the ROV model can quantify the value of uncertainty factors, and can improve the accuracy of value assessment. Through the sensitivity analysis, we find the trend and degree of the influence of each factor on the value of the project. Finally, we put forward some suggestions for the research results.

1 Introduction

In order to improve the efficiency of power resource allocation, the government issued a series of policies to promote power market reforms. In 2017, the National Development and Reform Commission and the Energy Bureau issued the "Notice on Conducting a Pilot Program for Distributed Power Generation Market Transactions", which introduces market-based trading mechanisms. In 2019, the Reform Commission and the Energy Bureau issued the "Notice on Announcement of the First Batch of Wind Power and Photovoltaic Power Generation Projects to be Connected to the Net in 2019", including a pilot list of market transactions for DPV. According to the pilot situation, we find that the most important market-oriented trading mode is the DTM [1]. The DTM refers to the direct transaction between DPV owners and power users. Which can significantly improve the economic efficiency of DPV owners, so the DTM is growing rapidly. According to the data released by the China Electricity Federation, from January to November 2019, the medium and long-term direct trading volume of electricity in the national electricity market was 1,967.93 billion kwh, it accounts for 30.2% of the total electricity consumption in the society, but the factors such as electricity price and transaction mechanism in the DTM are determined by the DPV owners in consultation with the power users, which has a high degree of uncertainty, it brings challenges to the accounting of economic benefits of DPV, so it is necessary to construct more accurate economic benefits model.

So far, many scholars at China and abroad have done a lot of research on the economic benefits of DPV. Z. Xin-gang constructed a DPV project revenue and cost model, through
the NPV method, the economic benefits of DPV projects can be obtained. However, the NPV method has limitations. This method ignores the impact of uncertainties[2]. When the external environment changes greatly, it will affect the accuracy of the calculation. Orioli A believes the uncertain factors that affect the economic benefits of DPV include feed-in tariffs, discount rates, and photovoltaic module prices[3]. Zhao XG believes that technological progress will also affect the economic benefits of DPV[4]. The ROV can effectively compensate for this. Z. Xin-gang Et al used real option method to calculate the value of DPV projects[5]. Zhao Weidong used the net present value method to calculate the economic value of the microgrid is negative, and used the ROV method to calculate the microgrid The economic value is positive, and it is believed that ignoring risk factors may result in erroneous investment judgment[6]. D. Loncar supplemented the applicable conditions for practical options, and considered that the ROV is most suitable when the following three conditions are met: highly uncertain about the future; flexible management space; and net present value near zero[7].

In this context, this paper builds a ROV model to evaluate the economic benefits of DPV project. Firstly, it analyses the cash flow, and then reflects the uncertainty factor through the electricity price fluctuation rate, so the value of uncertain factors can be quantified more accurately. It has theoretical and practical significance.

2 Economic benefit evaluation model of DPV

For the convenience of analysis, the following assumptions are proposed: (1) The investment can be completed immediately, regardless of the construction period. (2) The project investment is completed at the initial moment, and there is no additional investment.

2.1 Revenue model

"Direct trading mode" DPV projects, the owners of the revenue including electricity sales revenue \((ER^{D}_t)\) and subsidy revenue \((ER^{S}_t)\). So the project revenue is:

\[
ER^{D}_t = Elt_i * Ge_t * IC_t * P^{D}_t
\]  

Figure 1. Logical framework of the article.
\[ ER^S_t = Elh_t \cdot Ge_t \cdot IC_t \cdot P^S_t \]  
(2)

\[ Ge_t = Ge_{t-1} \cdot (1 - dr) \]  
(3)

\( ER^D_t \) and \( ER^S_t \) are all affected by the annual effective light hours (\( Elh_t \)), system power generation efficiency (\( Ge_t \)), installed capacity (\( IC_t \)). \( ER^D_t \) is related to the direct transaction electricity price (\( P^D_t \)), \( ER^S_t \) is related to the unit subsidy (\( P^S_t \)). The generation efficiency (\( Ge_t \)) is related to the battery aging rate (\( dr \)).

### 2.2 Cost model

In "direct transaction mode", costs including the initial investment cost (\( C_{inv} \)), operation and maintenance cost (\( C_{omc} \)), financing cost (\( C_{loan} \)), network fee (\( C_{tnf} \)), by the Eq4, Eq5, Eq6, Eq7.

\[ C_{inv} = u_{inv} \cdot IC_t \]  
(4)

\[ C_{omc} = C_{inv} \cdot q \]  
(5)

\[ C_{loan} = C_{inv} \cdot I_rate \cdot k \]  
(6)

\[ C_{tnf}^T = Elh_t \cdot Ge_t \cdot IC_t (P_0 - P_h) \]  
(7)

\( C_{omc} \) is calculated as a percentage of \( C_{inv} \), which is \( q \); \( C_{tnf}^T \) is related to the difference between the transmission and distribution price (\( P_0 \)) corresponding to the access voltage level of power users and the transmission and distribution price (\( P_h \)) of the highest voltage level involved in the market transaction of distributed generation.

### 2.3 Project value model

According to the expressions (1-7), when \( t=0 \), \( NCF_t = -C_{inv} \) when \( t>0 \), in the \( t \) year, the project cash flow is:

\[ NCF_t = ER^D_t + ER^S_t - C_{omc} - C_{loan} - C_{tnf}^T \]  
(8)

The NPV method takes the time value factor into account. The NCF of each year is discounted. After adding up, the NPV of the project can be obtained:

\[ NPV = \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t} - C_{inv} \]  
(9)

The DPV project is affected by many uncertainties. The ROV method can evaluate the value of the uncertain factors. the ROV model of the DPV project is:

\[ V_{B-S} = SN(d_1) \cdot e^{-rT} \cdot N(d_2) \]  
(10)

\[ d_1 = \frac{\ln\left( \frac{S}{K} \right) + \left( \frac{r+\sigma^2}{2} \right) T}{\sigma \sqrt{T}} \]  
(11)

\[ d_2 = d_1 - \sigma \sqrt{T} \]  
(12)

Then the total value of DPV projects including risk factors is:
\[ V = \text{NPV} + V_{B-S} = \sum_{t=1}^{n} \frac{\text{NCF}_t}{(1+i)^t} + C_{\text{inv}} + SN(d_1) - Xe^{-rT}N(d_2) \]  

(13)

\( V_{B-S} \) represents the ROV value, \( N(X) \) represents the standard normal distribution, and \( V \) represents the total value of the DPV project.

### 3 Case analysis

#### 3.1 Data

Mengdong launched electricity market transactions earlier and established power trading platform, so we can obtain more complete transaction data to further compare the advantages of the ROV method to the NPV method, the basic data are as follows:

| Parameters | Value | Unit |
|------------|-------|------|
| \( El_{h_t} \) | 1500 | h |
| \( Ge_t \) | 80% | / |
| \( IC_t \) | 50 | kWp |
| \( dr \) | 3% in the first year and 0.7% in the following years | |
| \( p_t^0 \) | 0.45 | yuan/kwh |
| \( C_{\text{inv}} \) | 250000 | yuan |
| \( q \) | 2% | / |
| \( I_{rate} \) | 5% | / |
| \( k \) | 70% | / |
| \( T \) | 25 | year |
| \( n \) | 15 | year |
| \( i \) | 6% | / |

(1) Feed-in tariffs and subsidies: On April 28, 2019, the National Development and Reform Commission issued the "Notice on Issues Regarding the Improvement of the On-grid Tariff Mechanism for Photovoltaic Power Generation", which adjusted the on-grid electricity tariff and subsidy standards for PV. According to the notice, the case’s benchmark feed-in tariff is 0.45 yuan/kwh, and the subsidy \( P_t^S \) is 0.18 yuan/kwh.

(2) Network fee: In the DTM, the owner of the DPV project must pay the network fee for grid companies, which is related to different voltage levels and corresponding transmission and distribution prices. The table is as follows:

| project | Electricity Price (yuan/kwh) |
|---------|-----------------------------|
|         | <1 kv | 1-10 kv | 35 kv | 110 kv | 220 kv |
| Electricity for General Industrial, commercial and other purposes | 0.3784 | 0.3413 | 0.2556 |     |     |
| Electricity for large industry | 0.1534 | 0.1464 | 0.1000 | 0.0810 |     |

Therefore, the unit over-grid fee = \( P_0 - P_h = 0.3413 - 0.2556 = 0.0857 \) yuan / kWh.
3.2 Calculating revenue and cost

Bring the data into formula (1-8) and calculate the project revenue, cost, and cash flow as follows:

![Figure 2. DPV project income, cost and cash flow.]

3.3 Calculating project value

(1) Investment expenditure refers to the amount invested by the owner for the construction of DPV projects. This paper assumes that the project investment is completed at the initial time without additional investment.

(2) Current value of the project is the sum of the discounted future cash flows.

(3) Since the risk-free interest rate will not change much in the short term, this paper chooses the five-year treasury bond interest rate.

(4) The investment validity period is the lifetime of investment opportunity of DPV project. According to [8], the investment opportunity of deferral is 1-3 years.

(5) The project value volatility refers to the future fluctuation of project value. When the volatility is 0, there is no difference between the calculation results of the ROV method and the NPV method. This index is the key index of the ROV model, it determines the accuracy of ROV method. Because the Mengdong is more mature in terms of DPV power generation, more complete transaction data can be obtained, so this article chooses natural logarithm method [8]. Because it is difficult to obtain the future data, the error of the extrapolation data is large, so the historical data is used instead. The formula is as follows:

\[ R_t = \ln \left( \frac{P_t}{P_{t-1}} \right) \]  \hspace{1cm} (14)

\[ \overline{R} = \frac{1}{n} \sum_{t=1}^{n} R_t \]  \hspace{1cm} (15)

\[ \sigma = \sqrt{\frac{1}{n-1} (R_t - \overline{R})^2} \]  \hspace{1cm} (16)

The benchmark feed-in tariffs in Mengdon over the past 16 years are as follows:
Table 3. Feed-in tariffs in Mengdon during 2004-2019.

| Year | FIT (yuan/kwh) | Year | FIT (yuan/kwh) |
|------|----------------|------|----------------|
| 2004 | 0.3000         | 2012 | 0.3049         |
| 2005 | 0.3150         | 2013 | 0.3184         |
| 2006 | 0.3246         | 2014 | 0.3104         |
| 2007 | 0.2740         | 2015 | 0.3035         |
| 2008 | 0.2840         | 2016 | 0.3068         |
| 2009 | 0.2860         | 2017 | 0.2785         |
| 2010 | 0.2874         | 2018 | 0.2978         |
| 2011 | 0.2879         | 2019 | 0.3035         |

Bring the FIT into formula 14-16, and get \( \sigma = 6\% \)

The data related to the ROV are summarized as follows:

Table 4. Parameters of real options.

| Parameter | Remarks                          | Unit   | Value     |
|-----------|----------------------------------|--------|-----------|
| X         | Investment expenditure           | yuan   | 250000    |
| S         | Current value of the project     | yuan   | 233,622.01|
| r         | Risk-free interest rate          | /      | 4.27\%    |
| \( \sigma \) | Volatility of project value     | /      | 6\%       |
| T         | Period of validity of investment| yuan   | 1-3年     |

Taking the investment validity period of 1 year as an example for analysis, the other data in Table 4 are brought into formula 10-13 to solve \( d_1 = -0.39 \), \( d_2 = -0.45 \), and \( V_{B-S} = 3181.96 \). The final result is shown in Figure 5:

Table 5. Calculation of NPV and ROV.

| Parameter | Value     |
|-----------|-----------|
| NPV       | -16,377.99|
| ROV       | 3181.96   |
| Total value | -13196.04|

According to Table, the NPV < 0, indicating that the project has no investment value. After considering the future uncertainties, the future uncertainty of the project is worth 3181.96, the total value of the project is -13196.04. After considering the risk factors, the amount of project losses is reduced.

4 Sensitivity analysis

The ROV is affected by various factors. In order to observe the influence of each factor, this paper chooses the variable range of -15% ~ 15%, taking the extension of 1 year as an example, we get the following results:
From the Fig 3 we can see the investment expenditure (X) is inversely proportional to the ROV. The current value of the underlying asset (S) and the volatility of the underlying asset value (σ) are directly proportional to the value of the ROV. σ has less influence on the value of the project ROV, X and S has larger influence on the value of the project ROV. Therefore, it is necessary to continuously strengthen the technology research and development and cost control[9], improve the efficiency of DPV generation, reduce the cost of power generation.

5 Conclusions

In this paper, we use the ROV method to study the direct-trading-mode DPV projects, considering the comprehensive effects of uncertainty of revenue and cost, the results show that the ROV method can quantify these uncertain factors. and the investment expenditure is inversely proportional to the ROV, the current value and the volatility of the underlying assets are directly proportional to the ROV. The ROV model established in this paper can contribute to the calculation of the value of DPV projects. From the above conclusions, the following enlightenment can be drawn:

(1) the value of DPV project is affected by many uncertain factors, Therefore, the logical relationship among various parameters and the method of value determination should be further explored, improve the accuracy of project value evaluation.

(2) DPV project technology to a large extent affects the costs of the DPV project, as well as the generation efficiency therefore, the DPV project technology will affect the current value and the volatility of the underlying assets. This paper shows that the current value and the volatility of the underlying assets has a greater impact on the value, therefore, we should increase R & D Investment and pursue technological innovation.

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