A Structure optimization method used in microgrid

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Abstract. This paper takes a large photovoltaic plant as a pilot platform to research the microgrid. In the microgrid, DC bus is the key structure, photovoltaic panels are the micro power source, lithium iron phosphate batteries are the energy storage device, and four converters are used as energy conversion device. This paper studies its specific characters such as component unit, control strategy, monitoring system and investment model, the paper builds a valuation model in the investing of energy micro system by using discounted cash flow model. According to power cost model, ecological and economic benefits are analysed and summarized, providing reference for the further application of construction on photovoltaic micro grid projects.

1. Introduction
With the rapid development of economic, the power industry is facing more and more environmental problems and energy issues are becoming increasingly significant. The demand for energy is increasing while the amount of fossil fuel is decreasing. In order to solve these problems, the research of new energy micro grid has gradually been paid more attention to in the power industry. The improvement of economy and stability is very important for the operation of a micro-grid. A reasonable system structure can not only coordinate all the units, but also improve the overall performance of the micro-grid to ensure the power quality and the return of the investment [1-4]. This paper takes a large photovoltaic plant as a pilot platform to research the micro grid. In the micro grid, DC bus is the key structure, photovoltaic panels are the micro power source, lithium iron phosphate batteries are the energy storage device, and four converters are used as energy conversion device. This paper studies its specific characters such as component unit, control strategy, monitoring system and investment model [5-7]. First, this paper sets up the hardware structure of the microgrid system, builds a valuation model in the investing of energy micro system by using discounted cash flow model. According to power cost model, ecological and economic benefits are analysed and summarized, providing reference for the further application of construction on photovoltaic micro grid projects [8]. The photovoltaic micro grid project studied by this paper has been put into operation in the northern province. This paper has introduced the construction, operation and detection of the project in detail. Therefore, the micro grid illustrated in this paper can be applied universally in many kinds of photovoltaic plants[9-10].

2. Structure of microgrid
With the rapid development of economic, the power industry is facing more and more environmental problems and energy issues are becoming increasingly significant. The demand for energy is
increasing while the amount of fossil fuel is decreasing. In order to solve these problems, the research of new energy micro grid has gradually been paid more attention to in the power industry. The improvement of economy and stability is very important for the operation of a micro-grid. A reasonable system structure can not only coordinate all the units, but also improve the overall performance of the micro-grid to ensure the power quality and the return of the investment. The micro power grid structure is shown in Figure 1. Where there are PV DC/DC inverter, Batt DC/DC bi-direction inverter, Load DC/AC inverter, and power AC/DC bi-direction inverter. The DC BUS is 750V, and the AC BUS is 380V. The micro power grid is composed of 4 inverters, the capacity of each inverter is 100kW.

![Figure 1. Structure of micro power grid](image)

3. Investment financial model of microgrid
Photovoltaic microgrid project has its unique investment properties. On the one hand, after the completion of the project, there is no need for continuous input of human, material and financial resources, and no need for operation-oriented project costs such as marketing and sales management. In addition to the normal maintenance management, after the completion of the construction and start-up of the photovoltaic power station, that is, it will no longer involve large expenses, and there is no need for large-scale maintenance force input. On the other hand, after the completion and operation of the project, the two ways of "self-use" and "balance online" will help the project to obtain extremely stable income cash flow, so it has a better investment effect. In engineering applications, photovoltaic construction projects are often as investment products with fixed rate of return. In the later stage of project construction, there are still a lot of opportunities for capital operation, such as using ABS for enterprise asset mortgage, packaging and listing for social financing, project pledge for future income replacement and so on.

Microgrid system contains energy storage side, power generation side and control side, which can exist as a relatively independent unit and has a broad application prospect. At the same time, it also has a good investment and application value. Therefore, the analysis of investment income by means of financial model construction is of great significance for the construction of micro-grid photovoltaic power station. The installation cost, power generation efficiency and operation cost of photovoltaic system have an important influence on the income of photovoltaic power station.

The main method adopted in this paper is the future cash flow discounting method, which is to calculate the return on investment of photovoltaic micro-grid power station by calculating the internal rate of return. At the same time, this paper also puts forward the corresponding kWh cost model to measure the kWh cost of any photovoltaic micro-grid project, and compares it with the current desulfurization electricity price cost and social comprehensive treatment cost. Finally, several ways to improve the income of photovoltaic microgrid are proposed.

3.1 Investment financial model of microgrid
In this paper, the cash flow discounting method is used to build the financial model and calculate the rate of return. Discounted Cash Flow (DCF) refers to the company's expected de-levered cash flow, which is called Unlevered Free Cash Flow (UFCF) and Present Value (PV). Normally, this paper
converts the cash flow of a project for 5-7 years into the final value. However, since the construction of photovoltaic power station project has a 25-year cycle, this paper adjusts it to a 25-year cycle. The total value of the project is the present value sum of all cash flows in the forecast period, and the calculation formula is shown in Equation (1).

\[
DCF = PV_1 + PV_2 + \ldots + PV_n + PV_{last}
\]  

(1)

The NPV of a project refers to discounting the overall operating cash flow of the project according to the current rate of return, so as to obtain the net cash flow of the project, as shown in Equation (2).

\[
NPV = \sum_{i=1}^{n} \frac{(\text{cashflow}_{in} - \text{cashflow}_{out})}{(1 + r)^i}
\]  

(2)

When NPV is equal to 0, the \( r \) value is the internal rate of return (IRR) of the project, which is called the internal rate of return (IRR). The internal rate of return (IRR) can be used as the main basis for the project investment return. DCF cash flow discounted method is the most technical valuation method in the current project valuation, which mainly depends on the cash flow of the project. It is the best way to reflect the real value of the project. By filling in the financial analysis parameter table, the detailed calculation of different photovoltaic microgrid systems is realized. In the financial analysis parameter table, the more important specific parameters are as follows:

1. Installed capacity of micro-grid: Installed capacity of micro-grid, as an important parameter to calculate the total generating capacity of the project, is an important parameter to calculate the discounting and generating capacity of the equipment;
2. PV feed-in price: PV grid feed-in price is directly related to the sales income, which is related to desulfurization price, national PV project subsidy, benchmark price, and feed-in strategy, etc., and is an important parameter related to income acquisition;
3. Annual power generation equipment utilization time: the annual power generation hours available at the location of the photovoltaic project can be inquired according to solar-gis and other websites. It is closely related to the specific project location and is an important parameter with a relatively high correlation with sales revenue;
4. Investment cost per watt: The investment cost per watt of photovoltaic microgrid project is mainly related to battery price, photovoltaic cell price, module price, installation cost and other expenses, and is an important parameter to consider project investment cost;
5. Financial parameters: Mainly include the term of loan interest rate, loan interest rate and other financial parameters, which are important parameters affecting the financial cost of investment;

In this model, the salvage value ratio of 3% is adopted, and the straight-line method is used for depreciation treatment in 15 years. The annual depreciation expense has an impact on the operating cash flow, which affects the final asset valuation.

Working capital is an indicator of the balance between a company’s current assets and current liabilities, which can be calculated as: **Working capital = current capital - current liabilities**.

If the working capital is positive, it indicates that the project is more likely to cover the upcoming liabilities. The working capital can mainly be regarded as an indicator representing the near-term liquidity of the company. In this model, the fund sources of the project are mainly profit, depreciation and amortization, long term and short term borrowing, tax deduction, etc. The fund utilization of the project is mainly in the aspects of fixed asset investment and working capital. The surplus fund can be regarded as the operating fund of the project.

The cash flow statement is a statement that measures how much cash the item has generated or spent over a period of time. In this project, it is mainly the operating cash flow, reflecting the net cash flow of the project. Photovoltaic projects also have no other investment cash flow and financing cash flow. Cash inflow is mainly reflected in desulfurization power generation revenue, national and provincial subsidies, fixed assets average value, working capital recovery, tax deduction, etc. The cash outflow is mainly the investment, working capital, operating cost, tax and other parts of fixed assets, and the net cash flow of the remaining balance should be used as the basis for calculating the internal rate of return. Multiple circular references are required as you synthesize the tables. This circular reference is closely related to debt and interest. For example, the change of debt will lead to the change of interest income, income statement and cash flow statement. Therefore, it is necessary to build the valuation
model by integrating the above multiple tables, and finally calculate the cash flow of the project and get the internal rate of return of the project.

3.2 Cost and social effect of microgrid per kWh

In addition to the financial modeling and calculation of the internal rate of return for the photovoltaic microgrid system from the Angle of return rate, the calculation of kWh cost by using the established financial model is also a popular algorithm at present. After calculating the cost per kilowatt hour, the cost per kilowatt hour generated by the current photovoltaic microgrid system can be obtained, so as to compare with the current desulfurized coal price and evaluate the social effect, including environmental cost and pollution treatment cost. There are two definitions about how to define and calculate the kWh cost. One is a definition widely used in domestic financial models, which is mainly calculated based on initial investment, residual value of the project, operating cost and power generation. The calculation Equation is as follows (3):

\[
LCOE = \frac{I_0 - V_R + \sum_{n=1}^{25} (O_n + R_n)}{\sum_{n=1}^{25} G_n}
\]

In Equation (3), the meanings of the parameters of kWh are shown in Table 1.

| Name | Parameters Description |
|------|------------------------|
| \(I_0\) | Total investment in the first year: initial investment in the project |
| \(V_R\) | Equipment salvage value: Equipment salvage value after 25 years of project operation |
| \(O_n\) | Operating costs: The operating costs of the project up to year \(n\) |
| \(R_n\) | Interest cost: The interest cost paid to operate the project until year \(n\) |
| \(G_n\) | Electricity generation: The amount of electricity generated by the project up to year \(n\) |

In Equation (1), the comparison between the total investment cost of the project and the total power generation is mainly used. However, an important problem of this financial model is that time cost is not taken into account, that is, capital will depreciate gradually with the change of time, so the time cost is relatively simple.

However, within the international applicable scope, the calculation formula of kilowatt hour cost which takes time into account and discounting is relatively widely applied. The calculation Equation is as follows (4):

\[
LCOE = (I_0 - \frac{V_R}{(1+r)^n} + \sum_{n=1}^{25} (O_n + R_n)(\sum_{n=1}^{25} G_n(1+r)^n)^{-1}
\]

In Equation (4), all produced and the value of the investment should be converted into present value according to the discount rate \(r\) to calculate its "time value", including power generation, have is a discount according to the different time, in turn, fully embodies the time value of the different, this way of calculation is more conform to the logic of thinking way of calculation, but a complex model, not considering domestic commonly so. Generally speaking, there is a big gap between the domestic and international kWh cost models. The domestic kWh cost model is relatively low, while the international kWh cost model is relatively high. Generally, it can be considered that the intermediate value of the two can be used as the exact value of kWh.
Through the plan, it can be calculated that the cost per kilowatt hour of microgrid is between 0.45 and 0.76 yuan, which can be approximately considered as 0.7 yuan or so, which is still relatively high compared with the desulfurization price. However, if compared with the cost of thermal power generation, it can be found that the cost per kilowatt hour contains relatively large social costs, which are similar to the cost of thermal power generation after comprehensive consideration.

Table 2. The pollution shadow cost of thermal power generation

| Contaminant name | kWh cost (yuan) | Contaminant name | kWh cost (yuan) |
|------------------|----------------|------------------|----------------|
| SO₂              | 0.1795         | NOₓ              | 0.0366         |
| CO₂              | 0.1865         | Dust             | 0.1065         |

Desulfurization price is mainly in the form of thermal power generation. In the process of thermal power generation, harmful gases such as sulfur dioxide, nitrogen oxide and dust pollutants will be eliminated. People are also paying huge costs and costs in terms of eliminating air pollution, dealing with the greenhouse effect, and achieving sustainable development. These costs should also be factored into the social costs of coal-fired power generation. In this paper, the shadow cost method is used to calculate the cost of pollution caused by thermal power generation. Table 2 shows the pollution shadow cost of thermal power generation.

The cumulative shadow cost of these pollutants is 0.5091 yuan, so society provides a non-visual subsidy for thermal power, but it should still be included. According to relevant national regulations, the price subsidies of various environment-friendly thermal power plants are shown in Table 3.

Table 3. Environment-friendly thermal power price

| Markup category          | Premium prices    |
|-------------------------|-------------------|
| Desulfurization electricity price | 1.5 fen/kWh       |
| Denitrification electricity price | 1 fen/kWh        |
| Dust removal electricity price | 0.2 fen/kWh      |
| Ultra-low emission       | 0.032 yuan/kWh    |
| Summary                  | 0.027 yuan/kWh    |
| Total environmental cost of thermal power | 0.5091 yuan/kWh |

If this article will state subsidies cost into consideration, in the field of photovoltaic (PV) countries currently set for photovoltaic industry benchmark pricing policy subsidy is 0.42 yuan/kWh, in this condition, the degree of photovoltaic electricity cost and thermal power but the need for social comprehensive governance is similar, the cost of photovoltaic power generation has the effect of parity on the Internet.

4. Investment application of microgrid

The core parameters of the 100kW micro grid designed in this paper are as follows: Installed capacity: 1010,000 kW. This area belongs to the second-class lighting resource area, and enjoys the standard of 0.80 yuan photovoltaic power price, and the desulfurization power price is 0.3005 yuan/ kWh. GPS positioning can be obtained, and solar-gis positioning can be obtained. The average annual available hours in this region are 1,643 hours. According to the existing construction investment, the construction cost per watt of the microgrid project is calculated as shown in Table 4. Through calculation, this paper concludes that the total investment amount of the project is 940,000 yuan, and the total investment income is 8.44%, and the cost can be recovered in 10 years. The 10-year full investment cash flow statement is shown in Figure 2. The yield rate of the project is higher than the
general interest rate, which means that the project can be used as a long-term fixed investment project for project reserves. Moreover, the investment amount of the project is small, which can be accepted by the general photovoltaic power station, and can be used as the photovoltaic power plant and other related development methods.

Table 4. Environment-friendly thermal power price

| Number | Construction content                        | Per watt cost (yuan) | Cost of percent |
|--------|---------------------------------------------|----------------------|-----------------|
| 1      | Solar monocrystalline silicon cell module   | 4.30                 | 45.77%          |
| 2      | Inverter                                   | 0.90                 | 9.58%           |
| 3      | Cable bridge                               | 0.10                 | 1.06%           |
| 4      | Junction box                               | 0.076                | 0.81%           |
| 5      | Cement based                               | 0.264                | 2.81%           |
| 6      | Manual adjustable bracket                  | 0.569                | 6.06%           |
| 7      | DC cable                                   | 0.254                | 2.70%           |
| 8      | Communication cable                        | 0.041                | 0.44%           |
| 9      | The project design                         | 0.167                | 1.78%           |
| 10     | Cost of installation                       | 0.036                | 0.38%           |
| 11     | Personnel costs                            | 0.188                | 2.00%           |
| 12     | Monitoring system                          | 0.50                 | 5.32%           |
| 13     | Energy storage system                      | 2.00                 | 21.29%          |
|        | Summary                                    | 9.40                 | 100%            |

According to the calculation, the cost per kWh calculated by the domestic formula is 0.45 yuan/kWh, and the cost calculated by the international formula is 0.76 yuan/kWh, which basically reaches the level of sustainable operation after the current state subsidy. From the perspective of investment income, the pilot project of microgrid technology is successful and has the value of promotion.

In this paper, the main parameters of investment in the micro-grid system are defined, and the financial model building and investment return evaluation of dc micro-grid construction are realized. The specific results are as follows:
(1) The financial calculation form suitable for the general microgrid system was established, and the financial calculation model based on the DCF valuation model was built, including multiple forms such as the income statement, the statement of capital flow, the balance sheet, the depreciation schedule and the capital operation statement.
(2) Use the existing multiple tables for comprehensive calculation, and use the multi-step cycle method to calculate the project valuation and investment return through the project cash flow.

(3) On the basis of project valuation and internal rate of return calculation, complete the improvement function of two KWH cost models in the model, complete the calculation of KWH, a model to measure social and economic effects, and compare the social cost generated by thermal power generation.

(4) Taking the photovoltaic power station studied in this paper as an example, the project investment return rate, project valuation, kilowatt hour cost and other economic and financial indicators of the 100kW DC microgrid system are calculated, and the research and summary are carried out, which is suitable for expansion as a typical case.

5. Conclusion
The improvement of economy and stability is very important for the operation of a micro-grid. This paper takes a large photovoltaic plant as a pilot platform to research the micro grid. In the micro grid, DC bus is the key structure, photovoltaic panels are the micro power source, lithium iron phosphate batteries are the energy storage device, and four converters are used as energy conversion device. This paper studies its specific characters such as component unit, control strategy, monitoring system and investment model. The paper builds a valuation model in the investing of energy micro system by using discounted cash flow model. According to power cost model, ecological and economic benefits are analyzed and summarized, providing reference for the further application of construction on photovoltaic micro grid projects.

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