Research on Economic Returns of Distributed Photovoltaic Power Generation Projects in Hunan

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Abstract. Photovoltaic power generation has been practiced in the application field in recent years. Distributed photovoltaic power generation has now entered the stage of large-scale, and government subsidies at all levels are being reduced. Will distributed photovoltaic power generation projects still have the necessary investment and development advantages in the future? We selects Hunan Province, China as the research area and analyzes the economic returns and development of distributed photovoltaic projects. The method of esmiting economic returns is the IRR, NPV and payback period. According to the analysis conclusion, it is believed that distributed photovoltaic power generation still has advantages, and the investment strategy and suggestions for distributed photovoltaic power generation projects in Hunan.

Keywords: Photovoltaic Power Generation, Economic Returns Evaluation, Distributed PV-power Industry.

1. Introduction
Solar photovoltaic power generation is a way to effectively use solar energy to produce clean energy. With the emergence of various environmental problems in China, clean energy that can maintain the balance between economic development and environmental protection has become increasingly important. And it has become an important strategic emerging industry in China. China's photovoltaic power generation industry needs domestic purchasing power, because its photovoltaic products have encountered a "double reversal" policy and are unsalable in the European and American markets. In the past ten years, the photovoltaic power generation industry has been developed in many areas in China and has made important contributions to optimizing the energy structure and improving the ecological environment.

There are two application forms of photovoltaic power generation in China. The first is the application form of photovoltaic power generation in large-scale areas, and the second is the application form of distributed photovoltaic power generation. Photovoltaic power generation requires two specific conditions, one is sunlight exposure, the other is the construction of the entire equipment for photovoltaic power generation. Distributed photovoltaic power generation projects, which is a form of photovoltaic power generation, are relatively common in practice. They are defined as small distributed photovoltaic power generation facilities with less than 6 megawatts total assembly capacity and small distributed photovoltaic power station with 6 to 20 megawatts total assembly capacity, having the functions of short-distance power generation, grid connection and conversion, and can be
used in residential houses. At present, the technology of distributed photovoltaic power generation has approached maturity at the technical level, but the business model is still not good, the internal market momentum has not yet formed, and the development is still relatively slow.

The measurement method of distributed photovoltaic power generation projects is more complicated than that of general power stations. The clarification of the grid connection mode of photovoltaic power generation projects comes first. There are currently three types of distributed photovoltaic power generation projects, all self-usage, mainly self-usage and the leftovers selling to grid companies, and all selling to grid companies, all self-use mode means that the power generation can be fully consumed nearby [2]. The factors affecting photovoltaic power generation revenue include installed capacity, annual effective utilization hours, annual module decay rate, self-use electricity price, desulfurized coal-fired electricity price, benchmark electricity price, and subsidized electricity price. After that, we often use the net present value, investment payback period, and internal rate of return to analyze different benefits.

Research on the operation mode of distributed photovoltaic is still at preliminary stage. There is little consideration of the impact of changes in the Internet and subsidy policies. As of the end of 2019, Hunan Province has built a total of 3.4386 million kilowatts of grid-connected photovoltaic power generation projects. It is estimated that by the end of 2020, the province's grid-connected photovoltaic power generation will reach 4.3 million kilowatts. In consideration of the natural conditions in Hunan, photovoltaic power generation should be distributed mainly, focusing on areas with concentrated loads and high electricity prices such as industrial parks, commercial clusters, and public facilities. The distributed photovoltaic power generation projects in China are mainly connected to the power grid of 20kV and below, and are built on building roofs and auxiliary sites. In this study, we mainly discuss distributed photovoltaic power generation projects in Hunan.

2. Calculation basis

2.1. Annual power generation of photovoltaic power generation system
Solar photovoltaic power generation system consists of a square solar cells, and an inverter controller and other components. The capacity is mainly determined by the average annual power generation amount of solar radiation, solar photovoltaic power generation efficiency and the board area. Annual generation capacity of distributed PV system is

$$E_y = \eta \cdot P \cdot D_T(y) \times 10^{-3}$$

Where, $E_y$ is the annual effective power generation of solar photovoltaic system (kWh/year); $P$ is the total peak power (W); $\eta = \eta_f \cdot \eta_i$ is the efficiency of converting the peak watt power output by the solar photovoltaic array into AC power, taking 0.8~0.92; $D_T(y)$ is the annual peak sunshine time.

2.2. Electricity price and subsidy standard analysis
In order to reduce construction and operating costs, China’s distributed photovoltaic power generation policy encourages project owners to invest in their own construction or to develop distributed photovoltaic power generation projects intensively with energy management companies. The power generated can only choose all self-usage or mainly self-usage and the leftovers selling to grid companies.

This study considers the three modes of distributed photovoltaic power generation system power generation of 100%, 80% and 50% of self-usage. According to the general industrial and commercial electricity prices in Hunan Province, the voltage levels are divided into four levels, which are less than 1KV, 1-10KW, 35KV-110KV, and 220KV. The corresponding average electricity prices are 0.8280, 0.8080, 0.7880, and 0.7680 yuan/kWh [13]. In this study, the general industrial and commercial
electricity price of 1-10kV is selected, which is 0.8080kwh, and the online sales electricity price is calculated according to the current thermal power benchmark price of 0.45yuan/KWh.

The subsidized electricity price is an important factor affecting the economic benefits of photovoltaic power generation projects. There are usually national subsidies, provincial subsidies, and municipal subsidies. Provincial subsidies and municipal subsidies are local subsidies. The subsidies vary from province to city. The state subsidy is showing a declining trend, from 0.42yuan/kWh in 2017. The latest announcement on the National Development and Reform Commission website stipulates that for industrial and commercial distributed photovoltaic power generation projects (that is, distributed except for household use) that adopts the "self-generated, self-used, and remaining selling to grid companies" model, the total power generation subsidy standard is adjusted to 0.08yuan/kWh; The subsidy standard for the full power generation capacity of household distributed photovoltaic in the mode of "self-generated, self-used, and remaining selling to grid companies" and "all selling to grid companies" mode is adjusted to 0.05yuan/kWh [13].

Table1. Comparison of electricity prices in different modes.

| Modes     | Self-generation and self-usage | Selling to grid companies | Price (yuan/kWh) |
|-----------|--------------------------------|---------------------------|-----------------|
| Mode1     | 100%                           | 0%                        | 0.808           |
| Mode2     | 80%                            | 20%                       | 0.816           |
| Mode3     | 50%                            | 50%                       | 0.709           |

In summary, electricity prices are different under different self-use ratios of on-grid electricity mode. The electricity price for 100% self-use is 0.808yuan/KWh, the price for 80% self-use electricity is 0.816, and the price for 50% self-use electricity is 0.709yuan/KWh. It can be seen that due to the existence of subsidized electricity prices, the economic efficiency of power generation under the 80% self-use mode is higher.

3. Economic benefit evaluation of PV projects in Hunan Province

3.1. Project cost analysis

The cost of distributed photovoltaic power generation projects is mainly divided into construction investment costs and operating costs [5]. Among them, the construction investment cost mainly includes system design costs, purchase costs of photovoltaic modules, inverters, brackets and other equipment, personnel employment costs, project insurance costs, and customer line transformation costs. Maintenance costs mainly include wages of related personnel, cleaning costs of photovoltaic modules, and maintenance personnel training costs. The calculation formula for the cost of each part is as follows:

\[
C = I_g + \sum_{t=1}^{n} (M_g + T_g + q)(1+i_c)^t
\]  

(2)

Where, \( I_g \) is the initial total investment; \( M_g \) is the annual operating cost; \( q \) is the small expenses such as power outage loss; \( i_c \) is the discount rate, which generally refers to the capital cost rate required by the enterprise or the investment return rate required by the investor; \( t \) is the time point when the funds are generated; \( N \) is the life span of the photovoltaic system, and the contract energy management mode is the contract period.

Due to the short construction period of distributed photovoltaics, the time value of the initial investment can be ignored.

We takes a 20kw power generation project as an example. The supporting equipment of a distributed photovoltaic power generation project includes photovoltaic modules, inverters, c-shaped...
steel brackets, T-shaped bases, triangles, direct connections, medium pressure, side pressure, stainless steel screws, and Net cages, cables, M4 connectors and auxiliary materials, etc. The total cost of these accessories is 3.3kwh watts. The direct material cost of the 20kw power generation project totals 66,000 yuan, and the manual installation cost is 4,000 yuan. When it is completed and ready for use, the construction cost of the entire power generation system totals 70,000 yuan. According to market data, annual operating costs are generally 1-3% of construction costs.

3.2. Economic benefit analysis

The income of distributed photovoltaic power generation mainly includes electricity sales income, on-grid electricity income, government subsidies, etc.

Power generation revenue is electricity price \( \times \) power generation.

\[
B_i = E_i \times P_i
\]

This study uses net present value indicators to analyze the economic benefits of distributed photovoltaic power generation projects, that is, from the first year when photovoltaic power generation is started to the final year when the final equipment is scrapped, and the project ends, the user will obtain the electricity generated for self-use or online the ratio of the sum of the present value of the economic benefits to the total cost of the project. Cash flow equals cash inflow minus cash outflow; cash inflow includes operating income, subsidy income, recovery of original value of fixed assets, and recovery of working capital; cash outflow includes construction investment, working capital, operating costs, business tax surcharges, and adjusted income tax, among which adjustments Income tax is only used to calculate the indicators after income tax; the indicators that need to be calculated include project investment financial internal rate of return (before income tax), project investment financial internal rate of return (after income tax), project investment financial net present value (before income tax), project investment financial net present value (after income tax), project investment payback period (before income tax), project investment payback period (after income tax). If the ratio is greater than 1, or even far greater than 1, it indicates that the project has economic benefits or the economic benefits of the project are better.

\[
NPV = \sum (B_i - C) (1 + I)^{-1}
\]

According to Table 2, different self-use ratios affect the economic benefits of power generation. According to Table 3, my country’s solar energy resources vary greatly from region to region. Type I resources are concentrated in parts of Northwest China, Type II resources are concentrated in parts of North China, Type III resources are concentrated in parts of North China and Northeast China, and IV and V are concentrated in parts of North China. East China, South China and Central China. Hunan Province is a category IV area. The annual average sunshine duration is between 1,400 hours and 2,200 hours. The total annual solar radiation is between 3,200 and 4,600 MJ/m2, and the annual average sunshine hours is 1,457 hours. For the convenience of calculation, the annual solar radiation amount takes the median value of 3900MJ/m2, and the annual average sunshine time under standard illumination is 4 hours [14]. For the convenience of estimation and analysis, the average sunshine duration of 1457 hours is selected. The completion of the project put into production after the annual generating capacity is 17484kW, and the power generation of the system will be reduced by 5% every 5 years of operation.

| Table 2. Comparison of solar energy resources in different areas. |
The power generation system has been in operation for 25 years, but the PV module warranty is 20 years, so assuming that the 20kw power generation system has been running for 20 years, considering the bank deposit and loan interest rates in previous years, and the general investment return rate of individuals and companies, in the present value coefficient of annuity, $i = 8\%$.

### Table 3. Investment benefits of distributed photovoltaic power generation projects.

| Mode     | NPV      | IRR | Payback Period/year |
|----------|----------|-----|---------------------|
| Mode1    | 2583.29  | 8%  | 9.1                 |
| Mode2    | 3799.23  | 8%  | 8.7                 |
| Mode3    | -6603.77 | 6%  | 11.2                |

The economic data such as the NPV (net present value), IRR (internal rate of return) and investment payback period of distributed photovoltaic power generation projects under different self-use ratios are shown in Table 3.

In general, this 20kw distributed photovoltaic power generation project has different economic benefits under different self-use ratios. In the case of all the electricity generated for mode2, which means 80% self-use, its total return period is 8.7 years, is economically efficient and has investment value.

### 3.3. Social Benefit Analysis

Traditional power generation methods produce carbon dioxide and other harmful gases, while distributed photovoltaic power generation converts solar energy into electrical energy. Carbon dioxide is not emitted during the power generation process. It can be seen that the application of distributed photovoltaic power generation is beneficial to environmental protection. Has social benefits.

### 4. Conclusions and investment recommendations

#### 4.1. Result

Distributed photovoltaic power generation system occupies a very important position in today’s energy utilization. This article conducts pre-financing analysis from the investment cash flow, especially in the calculation of cash inflow and cash outflow, all factors must be considered in order to calculate the most accurate result.

We can also see that the income return of distributed photovoltaic power generation projects, including government subsidies, combined with the country’s resources and environmental status, is a promising investment project with economic value and social benefits. At the same time, the attenuation rate of the modules that affect the power generation of the distributed photovoltaic system is a factor that has more room for improvement. In the design and construction of the photovoltaic power generation system, you can consider choosing photovoltaic modules with a smaller attenuation rate.
4.2. Suggestions
For investors, they can carry out in-depth research and analysis of the project in advance, and establish strict risk prevention measures and evaluation mechanisms during the project review stage. Establishing a cooperative and win-win relationship with the government, power grids, enterprises and other departments, and a sound cooperation mechanism and detailed risk sharing mechanism are also important.

For residents, considering the average capacity of a single household of household photovoltaics has increased year by year since 2017 and the budget and installation scale have also increased. They can consider the size of the installed distributed photovoltaic capacity according to their own electricity consumption. At the same time, it is possible to grasp the rush to install the distributed photovoltaic project, and due to the impact of overseas epidemics, the export of domestic photovoltaic equipment manufacturers is restricted to a certain extent. Therefore, residents can grasp the wind vents of photovoltaic projects that may appear in the recent stage.

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