Economic Analysis of 4MW Distributed Photovoltaic Power Generation Project Based on PVsyst Software Simulation

WANG Hong¹,a, WANG Zhijie²,b, FU Xiaolin³,c

¹ School of Economics & Management, Tongji University, Shanghai, China;
² Shanghai Dianji University, Shanghai, China;
³ College of Electrical Engineering, Shanghai Dianji University, Shanghai, China;
a wanghongpy@163.com, b wzjsdstu@163.com, c fuxiaolin12345@163.com

Abstract: We use PVsyst software to simulate and calculate the first year electricity generation of 4 MW distributed photovoltaic power generation project. In order to analyze and select the suitable power plant operation mode, the total generating capacity of photovoltaic power station in 25 years has been estimated by using component attenuation of 25 years. This research reports on the findings shown by PVsyst software that evaluates the economy aspects brought by two kinds of operation modes which are full grid access mode and spontaneous use of residual power grid access mode. The research content has reference value for the construction of roof distributed photovoltaic power station in China.

1. Introduction
This paper mainly uses the engineering design of PVsyst software to carry out simulation and calculation of the whole project, and draws the first year of power generation of the project, and then carries out economic analysis on the whole life cycle of the project.

2. PVsyst software simulation

2.1 Geographic location and its solar resources
The PVsyst software supports NASA and Meteonorm weather resource libraries. Due to the NASA meteorological database does not contain detailed hourly data, we chose to import hourly weather data from the city of Taizhou directly from the Meteonorm meteorological resource libraries.

2.2 Solar module
Researchers choose JKM270PP as the PV module with a power of 270Wp and the module has 60 solar cells.

2.3 String type photovoltaic inverter
The chosen PV inverter module is SG80KTL. The inverter is rated at 80 kW.

2.4 Photovoltaic array arrangement
This project selects a fixed bracket solution. The project was selected to install the components at an inclination of 25°.

2.5 PVsyst's simulation of the first year's power generation
Through the above-mentioned parameter settings of the operating mode and arrangement, the simulation model of the project was established. The first-year hourly meteorological data of Meteonorm was used to simulate the first-year power generation of the system.

The PVsyst simulation shows the overall efficiency of the system is 84.28%. It can be concluded that the total design of the system is reasonable.

3. Project economic analysis

3.1 Project Investment Estimation
The costs of the project includes many types of costs. According to the market survey, the various costs of the 4MW distributed photovoltaic power station project are considered in this paper.

It is estimated that the initial investment of the project is about 6,004 Yuan / Wp, the project design capacity is 4MWp, and the total investment is 2,4016,000 Yuan.

3.2 Analysis of national policy subsidies
The 2018 photovoltaic power generation feed-in tariff is shown in Table 1.
Tab.1 2018 PV power generation feed-in tariff list

| Resource Area         | PV benchmark on-grid price/kWh | Distributed power station subsidy/kWh | Remarks         |
|-----------------------|---------------------------------|--------------------------------------|-----------------|
| Ordinary power station| 0.55                            | 0.65                                 | Ordinary project|
| Poverty alleviation power station | 0.37          | 0.42                                 | Tax included price |

3.3 Calculation of power generation during the life cycle of the project

In practice, the efficiency of photovoltaic modules is declining every year, which means that the amount of electricity on the grid per year will decrease over time. Therefore, the attenuation of polycrystalline silicon solar modules must be considered when calculating the power of the power station. Table 2 is a table of attenuation parameters for polycrystalline silicon solar cell modules.

Tab.2 Attenuation parameter table of polycrystalline silicon solar cell module

| Years of installation | Power attenuation rate | Years of installation | Power attenuation rate |
|-----------------------|------------------------|-----------------------|------------------------|
| First year power decay rate | 1%                     | 10th year power decay rate | 8%                     |
| 5th year power decay rate | 4%                     | 25th year power decay rate | 20%                   |

According to the above attenuation parameters, because the power plant is guaranteed to have a decay rate of less than 20% after 25 years of operation, the annual component attenuation rate is estimated to be 0.8%.

From the graph, you can intuitively understand the numerical trend of the annual power generation of the entire power plant and the attenuation rate of the components. The component's 25-year time decays to 80% of the factory's time. Therefore, the annual power generation of the power station is gradually attenuated from the initial year's 4539000 kWh power generation to the 3,654,584 kWh power generation in the 25th year.

3.4 Project Benefit Analysis

3.4.1 Full-emission operation mode

The project is located in Taizhou City, Jiangsu Province, belonging to the Class III resource area. According to the latest on-grid tariffs set by the state for the photovoltaic industry in 2018, the photovoltaic power station uses its full-line operation mode to operate its Internet benchmark price of 0.75 yuan/kWh. The total revenue of the power station is calculated according to the following formula:

\[ W = P \times T \]

\[ P = P_{\text{solar energy}} \times T_{\text{photovoltaic price}} \]

\[ T_{\text{photovoltaic price}} = 0.75 \text{ yuan/kWh} \]

\[ T_{\text{local price}} = 0.391 \text{ yuan/kWh} \]

\[ T_{\text{subsidies}} = 0.359 \text{ yuan/kWh} \]

Combined with the power generation of the power station within 25 years of the life cycle and the national electricity price policy for the PV power station, the revenue of the project using the full-emission method for 25 years can be calculated. The project financial evaluation data is shown in Table 3.
### Tab.3 Project financial evaluation data of full-emission operation mode

| Number | Project name (unit)                        | Value  |
|--------|-------------------------------------------|--------|
| 1      | installed capacity (MW)                   | 4      |
| 2      | Design life (year)                        | 25     |
| 3      | first year power generation (kWh)         | 4539000|
| 4      | years average power generation (kWh)      | 4088792|
| 5      | Total investment of the project (yuan)    | 24016000|
| 6      | Project 25-year total income (yuan)       | 76676850|
| 7      | Average annual income (yuan)              | 3067074|
| 8      | Payback period (year)                     | 7.83   |

#### 3.4.2 Spontaneous use of residual power grid access mode

According to the national electricity price regulations for photovoltaic projects, the comprehensive income formula of distributed photovoltaic power plants with self-sufficiency and surplus electricity on-grid operation is as follows:

\[
W_{\text{year}} = W_{\text{subsidies}} + W_{\text{self-use}} + W_{\text{grid-connected}} \quad (3)
\]

\[
W_{\text{subsidies}} = W_{\text{solar energy subsidies}} \times P_{\text{year}} \quad (4)
\]

\[
W_{\text{self-use}} = P_{\text{self-use}} \times T_{\text{price}} \quad (5)
\]

\[
W_{\text{grid-connected}} = P_{\text{grid-connected}} \times T_{\text{price}} \quad (6)
\]

The financial evaluation data of the project is shown in Table 4.

### Tab.4 Financial evaluation data of spontaneous use of residual electricity on-grid operation mode

| Self-use ratio | Project name (unit) | Value                  |
|----------------|---------------------|------------------------|
|                | Total project investment (Yuan) | 24016000               |
| Self-use ratio 30% | Project 25-year total income (Yuan) | 78598804.19             |
|                 | Average annual income (Yuan)     | 3143952.168             |
|                 | Payback period (year)            | 7.64                   |
| Self-use ratio 50% | Project 25-year total income (Yuan) | 83726951.92             |
|                 | Average annual income (Yuan)     | 3349078.077             |
|                 | Payback period (year)            | 7.17                   |
| Self-use ratio 70% | Project 25-year total income (Yuan) | 88855099.65             |
|                 | Average annual income (Yuan)     | 3554203.986             |
|                 | Payback period (year)            | 6.76                   |

The project is calculated according to the 25-year operation cycle. Taking the self-use ratio in 30%, 50% and 70% as examples, the total income in the three cases was 78598804.19 Yuan, 83726951.92 Yuan, and 88855099.65 Yuan respectively. The investment recovery years were 7.64 years, 7.17 years, and 6.76 years, which met the relevant economic indicators.

#### 3.5 Comparison of the operation modes of the two power plants

After the above discussion and analysis, we have already learned the respective revenue status of the distributed photovoltaic power plants under two different operating modes. As it is shown in Figure 2.

Fig.2 Line chart of comparison of two modes of operation

Through the comparison of the two operating modes of the power station in Figure 2, the advantage of a power station operating in full-emission mode can only be seen when the proportion of self-use electricity is less than 20% and its advantages are not obvious.

### 4. Conclusion

A simulation of the first year of power generation of the project with 4MW photovoltaic power station has been
developed through PVsyst software. The simulation aims to carry out reliable references which help us analyze and select the suitable power plant operation mode. The differences between full grid access mode and spontaneous use of residual power grid access mode have been compared by us. It can be concluded that the advantage of a power station operating in full grid access mode can only be seen when the proportion of self-use electricity is less than 20% and its advantages are not obvious.

References

1. Zhou J, Kim S, Zhang H, et al. Consensus-based distributed control for accurate reactive, harmonic and imbalance power sharing in microgrids[J]. IEEE Trans. On Smart Grid, 2015:99.
2. Shi J, Wang L, Wang Y, et al. Generalized energy flow analysis considering electricity gas and heat subsystems in local-area energy systems integration[J]. Energies, 2017, 10(4).
3. Liu X, Mancarella P. Modelling, assessment and Sankey diagrams of integrated electricity-heat-gas networks in multi-vector district energy systems. Applied Energy, 2016, 167:336-352.
4. Jin Xiaolong, Mu Yunfei, Jia Hongjie, et al. Optimal day-ahead scheduling of integrated urban energy systems[J]. Applied Energy, 2016, 180:1-13.
5. Xue Xiaodai, Mei Shengwei, Lin Qiyou, et al. Energy internet oriented non-supplementary fired compressed air energy storage and prospective of application[J]. Power System Technology, 2016, 40(1):164-171.