Research on the Influence of Load Difference for Photovoltaic Micro-grid System Performance

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Abstract: In this paper, make use of PVSOL software studied the generation performance and Economic benefits of PV system at various inclinations. And then analyzed residential load, industrial load and commercial load system performance and self-sufficiency under different battery capacity. The results show that for Shanghai area, when the inclination angle of PV panel is about 23°, the annual total power generation of PV system reaches the maximum. The self-sufficiency rate of PV systems with industrial load is higher than commercial load, and the self-sufficiency rate of PV systems with residential load is the lowest. The self-sufficiency rate of PV systems with batteries are higher than PV systems without batteries, and the increment of installation power can increase self-sufficiency rate of the PV system.

Keywords: PVSOL, Photovoltaic systems, Economic benefits, Performance ratio.

1. INTRODUCTION

Global energy consumption is already in a state of rapid growth, solar energy as an inexhaustible supply of clean energy, more and more valued by people. The effective use of solar energy can not only alleviate the problem of energy shortage to a large extent, but also well implement the global theme of sustainable development. With the increasing energy crisis and environmental pollution, and the disadvantages of large power grid characterized by large units, large power grid and high voltage in operation, cost and safety are increasingly prominent, the development and utilization of new energy has become an important direction of the development of power grid [1].

The micro power supply and load can form “intelligent cell mode”, and the micro-grid and local load operate in coordination. that is, when the load changes, the output of the micro power supply adjusts accordingly with the dispatch, and the micro-grid will suppress voltage fluctuation at this time. When the micro-grid cannot operate in coordination with the local load, for example, the micro-grid that uses natural resources, such as wind power and PV system to generate electricity has poor schedulability, the local voltage stability may be affected to some extent after the micro-grid is connected to the power grid [2-4]. In the past 10 years, China's global share of polysilicon production has increased from 0.3% to 47.8%; The global share of PV module production has increased from 11% to 72.1%, and it has ranked first for nine consecutive years. The global proportion of new photovoltaic installations increased from 0.36% to 28.5% and ranked first for three consecutive years. The cumulative pv installation volume also increased from 1.35% to the world's first.

In terms of improving the efficiency of PV systems, there are also very big breakthroughs. High efficiency and low cost are the development trend of crystalline silicon solar cells, and N-PERT solar cells are one of the most concerned efficient crystalline silicon solar cells. The average conversion efficiency of N-PERT solar cells is 20.8%, up to 21.1%, and the efficiency of polysilicon can reach 19.10%.

Practical application of PV system there are two broad categories of domestic Photovoltaic and solar power station. Home photovoltaics are systems that install and use distributed solar energy to generate electricity on a home's own roof. In the practical household application of PV system, home photovoltaic has been greatly promoted in recent years due to its characteristics of small installation capacity, many installation points, simple grid-connection process and obvious direct income. Home pv is also one of the most subsidized forms of distributed photovoltaic power generation [5].

With the cost of generating electricity falling by the day, photovoltaic bidding can even rival that of thermal power. However, the main reason for the current decline in PV system costs is the decline in raw material costs caused by the global economic downturn, rather than the significant changes in PV system technology itself. As the economy recovered,

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rising material costs, falling or even abolish the subsidies, photovoltaic industry could enter the severe winter. In 2016, the National Development and Reform Commission proposed to reduce the subsidy of PV system. If the subsidy of photovoltaic power generation is reduced, the economy of PV system needs further study, and the payback period of PV system will be further extended. Compared with thermal power plants, the economic disadvantage will be more prominent.

2. PVSOL DATA SELECTION

In the course of PV micro-network performance and Economy simulation, software used for PV*SOL design software. This software can be used to build the PV micro-grid scheme and simulate the PV system. It is a photovoltaic design software with full functions and strong practicability. When constructing the PV micro-grid system, three kinds of grid-connected photovoltaic power generation system, grid-connected photovoltaic system with load and grid-connected photovoltaic power generation system with battery, can be established. You can select location-specific weather data, import it from Meteonorm, and create weather data based on actual weather conditions. At the same time, it can carry out 3D visualization planning and design of PV system, facilitating more detailed arrangement and planning of photovoltaic panels. PV systems can be planned to be installed on rooftops, complex buildings or vacant lots. Different installation positions have different shielding conditions. Trees and walls can be added in the design to simulate the installation of the PV system on the restoration site. In the design process can choose inverter, cable length and thickness material can also be modified.

PV*SOL photovoltaic design software such as PVsyst software with other big difference and advantage is can design load, can be designed according to different load types such as resident load, commercial load, heat pump, etc., each year can be divided into four seasons, according to each season working days, Saturday and Sunday to design load of the load of each hour every day. It is also possible to classify loads such as non-user-determined loads such as refrigerators, user-determined loads such as televisions, loads such as coffee makers that are only used for a short period of time, and different types of loads such as electricity for lighting. PV*SOL software can be used to simulate the photovoltaic micro-grid power generation, PV system performance, energy distribution in the micro-grid and economic benefits of the micro-grid [6-9].

For PV*SOL calculations, select the weather data for the Shanghai area, using 31º23'59" (31.4º) E and 121º27'35" (121.46º) N. Except for a few hills and mountains in the southwest, Shanghai is a flat and low plain, which is a part of the alluvial plain of the Yangtze River Delta with an average elevation of about 4 meters. The land terrain generally slopes slightly from east to west. The geographical location, weather condition, type of photovoltaic panel, inclination angle of photovoltaic panel and shielding condition of surrounding buildings will affect the power generation and economy of PV system. According to the historical meteorological data of Shanghai using Meteonorm software, the average annual irradiance in Shanghai is 1270kWh/m^2 and the average annual temperature is 17.4^{o}C.

The analysis of PV system power generation performance includes two parameters: self-sufficiency rate and system performance ratio. System self-sufficiency rate refers to the percentage of energy provided by PV system in the total load energy. System performance ratio is the ratio of PV system output to theoretical output. The system performance ratio formula is as follows:

Where, Yf stands for average power generation hours, Yr is peak sunshine hours.

3. POWER GENERATION PERFORMANCE OF PV SYSTEMS

3.1. Power Generation Performance of the System at Different Inclinations

In order to reduce the error, PV*SOL Example polycrystalline silicon photovoltaic panels are selected uniformly. Photovoltaic panels of 100W or 200W are selected according to different installation power. The orientation angle and inclination angle of photovoltaic panels are adjustable, and the orientation angle is due south. The energy yield and performance of PV system are shown in Figure **1** (3.6kW photovoltaic system is selected). It can be seen from the figure that the total energy yield reaches the maximum when the inclination angle is 22^o or 23^o.

The performance of the PV system with different inclination angles can also be described by system performance ratio. For a 3.6kW polysilicon photovoltaic system, when the inclination angle is 0^o, the performance ratio is 71.1%, and when the inclination angle is 26-29^o, the system performance ratio reaches the highest, 72.7%. With the continuous increase of

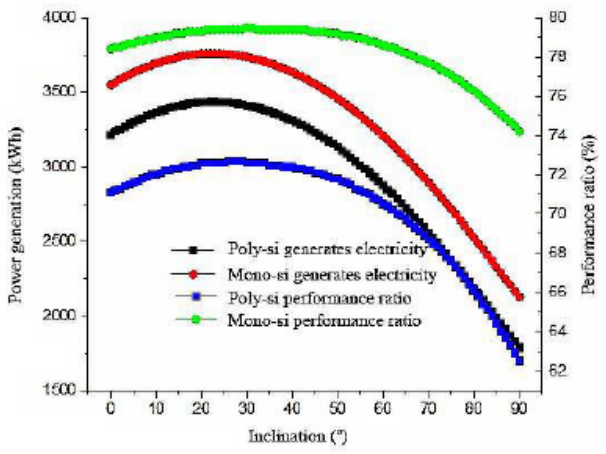


Figure 1: The performance ratio of poly-Si and mono-Si at various inclinations.

inclination angle, the performance ratio of the system decreases. When the inclination angle is 90°, that is, when the boards are vertically arranged, the performance ratio is 62.5%. The performance of monocrystalline silicon panel is larger than that of polysilicon, when the inclination angle is 0°, the performance ratio is 78.4%, when the inclination angle is 30~31°, the performance ratio is the largest, reaching 79.5%, when the board is vertical 74.2%. If only the performance factor is considered and the cost factor is ignored, photovoltaic panels can still operate in the vertical state, and the performance ratio of photovoltaic panels does not change much with the change of inclination angle. Considering performance only, a photovoltaic curtain wall attached to the outside of the building can achieve a certain effect. Considering such factors as floor area and shadow occlusion, the inclination angle of photovoltaic panel of 27° is the best [10].

In order to more clearly analyze the variation of power generation under different inclinations, the power generation of photovoltaic panels with different inclinations in different months in the PV system is sorted out as Figure **2** and Figure **3**. According to the analysis in Figure **2**, it can be concluded that in different months, the optimal corresponding angle of power generation is different. In January, February, November and December, the best angle of power generation is about 30°. In April, May, June, July and August, the best Angle of power generation is about 10°. However, the total power generation reaches the maximum when the photovoltaic panel inclination angle is 22° and 23°, and the maximum power generation is 3435kWh. If the tilt angle of maximum power generation is selected every month, the total power generation can be improved by 4.19% compared with the tilt angle of 23 degrees.

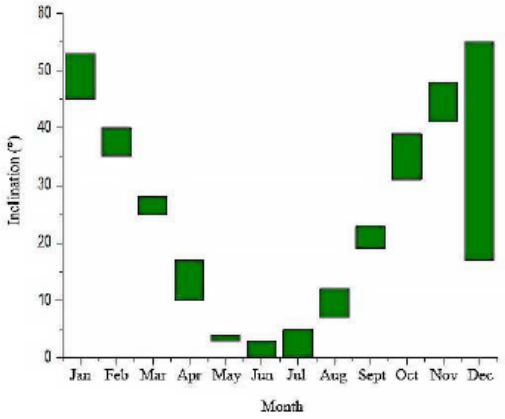


Figure 2: Monthly generation of poly-Si at various inclinations.

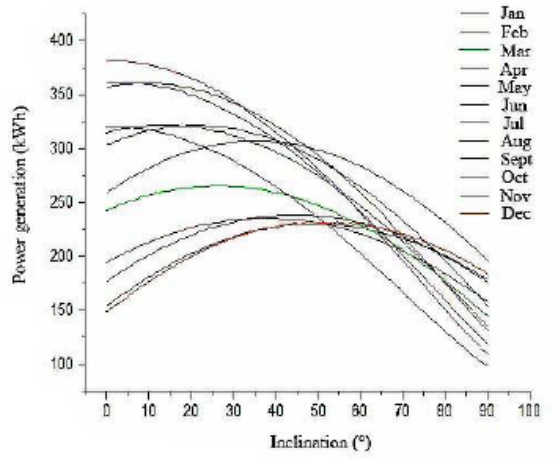
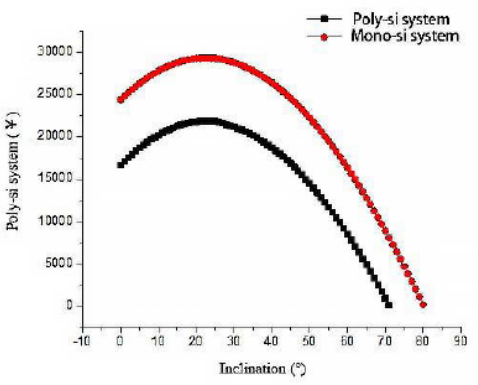


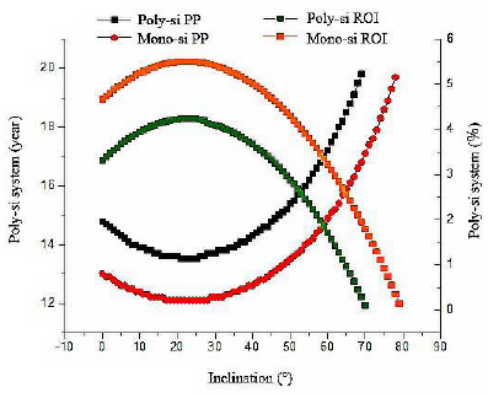
Figure 3: The optimum tiled angles in different months.

3.2. Economy of PV System at Different Inclinations

Economic evaluation indexes are used to analyze the economic performance of polysilicon and monocrystalline silicon PV systems with different inclinations, as shown in Figure **4**. For a 3.6kW PV system, there is a large economic difference with different inclination angles of PV systems. From the specific economic analysis results of polysilicon PV system, it can be seen that when the inclination angle is greater than 72°, the net present value is less than 0, there is no economy at all. When the inclination angle is greater than 70°, the payback period is more than 20 years. However, after 20 years, the PV system faces the reduction of photovoltaic panel power generation, and each equipment is in the state of recycling or facing scrapping. The life cycle of PV system is about 20 years, and the investment will be recovered in 20 years. When the inclination angle is greater than 70°,



a) NPV of PV system at various inclinations



b) PP and ROI of PV system at various inclinations

Figure 4: Economic benefits of PV system at various inclinations.

the total investment can not be recovered in the life cycle of PV system [11-14].

The ROI increases from 3.30% at 0^{o} to 4.23% at 23^{o}, and then decreases gradually until it reaches 0.00% at 71^{o}. From the perspective of economy, when the inclination angle of photovoltaic panels is greater than 70^{o}, the cost and performance of photovoltaic panels at present, the economy of PV systems is poor. Mono-si system has a high power generation and a low cost per kilowatt hour of electricity. Therefore, mono-si system has a relatively high net present value, short payback period, high return on investment and good economy [15].

3.3. Monthly Power Generation Performance of 3.6kW System

For a 3.6kW PV system, according to the historical weather conditions, the monthly power generation of the system can be obtained as shown in Figure **5**.

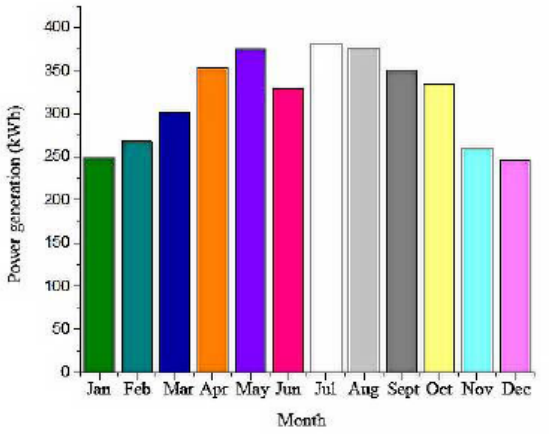


Figure 5: Monthly generation of 3.6kW PV system.

Shanghai belongs to the subtropical monsoon climate, full sunshine, abundant rainfall, mild and humid climate. In June and July, Shanghai is in the plum rain season, with larger rainfall and more rainy days. In June, photovoltaic power generation in Shanghai appeared a low point. In early July, due to the influence of plum rain season, the power generation was low. In mid and late July, under the influence of strong irradiance, the PV system generated more power [16].

The monthly irradiance and temperature changes of the PV system are shown in Figure **6** and Figure **7**. In the irradiance distribution curve, the blue box represents the irradiance on the horizontal plane, the red box represents the irradiance on the inclined plane, and the green line represents the irradiance when shadow and shielding are ignored. In January, February, March and October, November, December, horizontal plane of the irradiance less than the irradiance of inclined plane, in the rest of the light intensity is stronger, the level of irradiance rather than on the surface of the inclined surface irradiance, it can be seen throughout the year irradiance angle is not the strongest PV system in irradiance strong summer high capacity, On the contrary, the power generation is higher in winter when the irradiance is lower. According to the temperature change curve, the external temperature is larger than the module temperature, and the difference between the module temperature and the external temperature gradually increases as the external temperature increases.

Figure **8** shows the performance ratio of the system in each month. It can be seen from the figure that in May to September, when the temperature is relatively high, the power generation of the PV system decreases

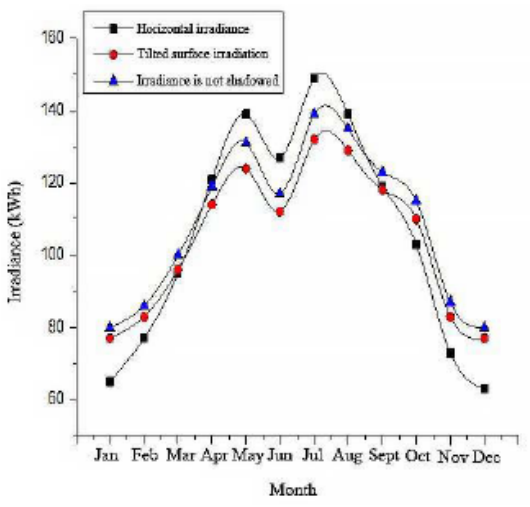


Figure 6: Monthly irradiance of 3.6kW PV system.

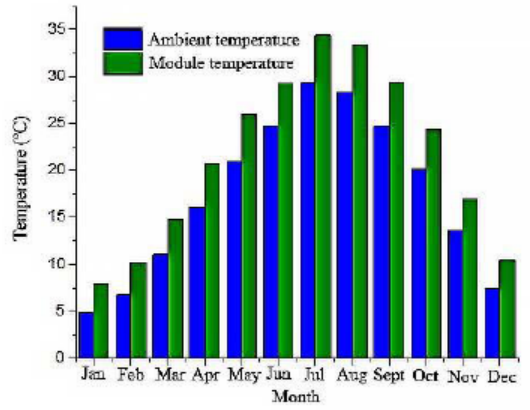


Figure 7: Monthly temperature of 3.6kW PV system.

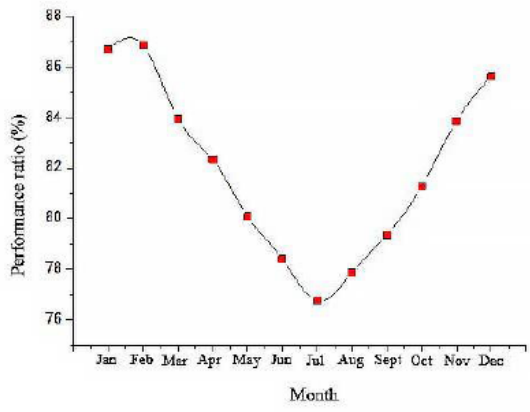


Figure 8: Performance ratio of 3.6kW PV system.

due to the high temperature. With the increase of illumination time, the photovoltaic module power will be attenuated to a certain extent. At the same time, there are other factors such as shadow occlusion, resulting in the performance of the PV system compared to the high irradiance in the summer.

4. PERFORMANCE OF PV MICRO-GRID SYSTEMS WITH BATTERIES

The estimation of solar panel power, load power consumption, battery capacity, etc., can be calculated by solar cell module and battery selection panel. Sunshine parameters can be selected as the standard coefficient of Shanghai, and the sunshine coefficient is 3.80336. If the total load power is set to 100W, the average working time is 8h per day. If the working voltage of the battery is 24V and the discharge depth is 80%, it can be estimated that the battery capacity is about 208.3Ah.

4.1. System Performance at Different Installation Powers

For an installed 3.6kW commercial load type system, the self-sufficiency rate of the system is 48.2% when no batteries. When the system is connected with 12V, 60Ah, 12kV, 140Ah, 12kV, 210Ah and 2kV, 3800Ah energy storage systems respectively, the self-sufficiency rate of the system increases gradually, but the increasing speed is slower and slower. If the photovoltaic panel installation power is increased from the original 3.6KW to 7.2KW, and then connected with 2kV and 1800Ah energy storage system, the self-supply rate is increased to 95.4%. It can be seen that photovoltaic panel installation power has a great impact on the self-sufficiency rate. Table **1** shows the self-sufficiency rate of the system under different installation powers and battery types.

Table 1: Self-Consumption Rate of PV System under Different Instillation Power and Battery Capacity

PV Panel Power (kW)	Battery Voltage (kV)	Battery Capacity (Ah)	Self-sufficiency (%)
3.6	12	60	52
3.6	12	140	56.1
3.6	12	210	62.3
3.6	2	3800	72.2
7.2	2	1800	95.4

When the photovoltaic panel installation power is 3.6kW, the self-sufficiency rate remains at a low level even if the battery capacity reaches 3800Ah. Therefore, to improve the self-sufficiency rate of the PV system, the photovoltaic panel installation power and battery capacity need to be increased at the same time. That is, under the condition of no battery, even if the

Table 2: Self-consumption Rate with Different Load Type

Load Type	PV Panel Power (kW)	Battery Voltage (kV)	Battery Capacity (Ah)	Self-sufficiency (%)
Residential Load	3.6	12	60	42.3
Residential Load	10.8	2	1800	95.7
Commercial Load	3.6	12	60	52
Commercial Load	10.8	2	1800	95.4
Industrial Load	3.6	12	60	54
Industrial Load	10.8	2	1800	92.5

installed photovoltaic panel power rises to a certain level, the self-sufficiency rate will not increase unlimitedly, that is, the PV system alone will not achieve 100% load satisfaction.

4.2. System Performance Under Different Loads

When the load type changes, the change of self-sufficiency rate is shown in Table **2**. Under the premise of the same battery capacity, when the photovoltaic panel installation power is low, the self-sufficiency rate of residential load is much lower than that of industrial load and commercial load , which is caused by the load characteristic curve of residential load and sunshine time being opposite. When the installed power of photovoltaic panels is high, even under the premise of the same battery capacity, the self-sufficiency rate of residential load, commercial load and industrial load is not different, but the self-sufficiency rate of residential load is greater than the self-sufficiency rate of industrial load and commercial load, which is opposite to the distribution trend of small installed power of photovoltaic panels [21, 22].

CONCLUSION

This article discussed the photovoltaic power generation system in Shanghai, the power generation and system performance ratio under different load types and different installation powers are analyzed. Also discusses the PV system under different angle of total output and economic benefits, not considering shadows shade, PV system optimum tilt angle is about 23^{o}, the choice not appropriate, if the angle system economy is bad, the system with a negative net present value. By analyzing the generating capacity of different dip angles in different months, the optimal dip angle corresponding to each month is obtained. If the battery is connected to the PV system, when the photovoltaic panel installation power is low, the self-sufficiency rate of different loads changes in the same trend as that without the battery. The opposite is true when photovoltaic panels are installed at high power. To achieve the best system performance, it is necessary to combine the appropriate photovoltaic panel capacity with the appropriate battery capacity. In the absence of batteries, the trend of self-sufficiency is that the industrial load is greater than the commercial load and the residential load.

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