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Upgrading of Photovoltaic System in An Existing Integrated Energy Park

Li Zhu[1], Yifan Jing [1*], Baoquan Yin[1], Fangfang Li[1]

1. Tianjin University, School of Architecture, Tianjin300073, China

ABSTRACT

Some industrial parks in China have completed the construction of green composite energy network and obtained the green building identification certification. However, after several years of operation, their renewable energy system has room to be updated. After combing the domestic and foreign studies, the current situation and prospects of the energy system in an industrial park in Tianjin, China are analyzed. Eight strategies were proposed from the three aspects of expanding photovoltaic area, upgrading photovoltaic equipment and improving management. The energy output, economic impact and environmental effects were calculated for each scenario. Results displayed that using the photovoltaic system upgrading strategy proposed in this paper, the renewable energy use of the integrated energy park can be effectively improved and enhance its demonstration significance in the whole society.

Keywords: industrial park, green energy, renewable energy, PV system

1. BACKGROUND AND INTRODUCTION

Industrial parks, including service parks, are an important building type, usually with a large area. The internal buildings include office, plant, dormitory, restaurant, parking lot, playground and other functional areas. The overall and per person energy consumption is high.

At present, there are some studies on improving energy conservation of industrial parks within China and abroad. Some research suggests reducing consumption of energy and resources [1], as well as generation of pollutants by buildings' layout [2], and hence achieve "sustainability" and "low carbon" [3]. Some studies accounted the GHG emissions of industrial parks [4], but they target at the operation of existing projects only, without taking the renewable energy into consideration [5][6].In other studies, the potential of industrial parks to use renewable energy sources such as photovoltaic is studied. An analysis of the solar potential carried out in a defined territorial context, intends to estimate the potential production of electricity from solar sources starting from a survey on the availability of the present surfaces. A study shows how the upgrading of public areas for parking, areas of interchange, or for the shelter of pedestrians in holding areas for public transport or in parking ones for cars can become an opportunity for energy production.[7] One fact is that their research subjects were not originally green parks. In terms of specific methods, such as increasing photovoltaic power generation, there are mainly two existing methods for PV potential analysis. The first one is based on data collection and uses formula and discount factor method for assessment, the factors are mostly estimates based on empirical data[8][9]; the second method relies on laser scanning modeling or photogrammetry. [10][11]

The North Park of the State Grid customer service center in Tianjin, China was put into operation in June 2015, with a total construction area of 142800 square meters. The park has 10 buildings, which can accommodate more than 2600 people for office and living. The park has realized the construction of integrated energy network and intelligent service Innovation Park, and has obtained the green building identification certification. Over the past five years, the average annual renewable energy in the park accounts for more than 32%, reaching a maximum of 58%.

Taking electric energy as the only external energy, the park has built a variety of energy conversion devices such as photovoltaic power generation, ground source heat pump and ice storage, and creatively used

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photovoltaic power generation trees, power generation bicycles and the first power generation floor tiles applied in engineering practice in China. It has applied four types of renewable energy such as solar energy, wind energy, geothermal energy and air heat in a large-scale and efficient manner. It operates and adjusts based on the energy network. The control platform realizes the comprehensive analysis, unified dispatching and optimal management of cold, heat, electricity and hot water in the park.

After five years of operation, the comprehensive energy system in the park has not only produced energy, played the role of energy conservation and carbon reduction, and produced economic and social benefits, but also gradually encountered problems such as damage and aging of equipment and decline in efficiency. During the covid-19 epidemic, the park experienced closed management. High intensity operation led to further increase in energy consumption. With these new situations and expansion, in order to maintain energy saving, high efficiency and environmental protection of the park, upgrading energy system is imperative.

Photovoltaic system upgrade is the focus of this round of work. There have been some studies on photovoltaic upgrading methods of existing parks or buildings, but more attention has been paid to the promotion and optimization of unilateral factors such as building orientation selection or minimizing installation and operation costs [12] [13]. At present, there is still a lack of comprehensive photovoltaic optimization strategy research on the scale of the park. This paper will be a useful exploration for this field.

2. ANALYSIS ON CURRENT SITUATION AND RENEWAL OBJECTIVES OF SOLAR UTILIZATION SYSTEM IN STATE GRID CUSTOMER SERVICE PARK

2.1Existing photovoltaic system in the park

At present, the photovoltaic power generation in the State Grid customer service park is for self use, and all the generated power is consumed locally, which is mainly used for the production and domestic power demand of various buildings. The photovoltaic power generation system has been built on the roofs of 8 R & D buildings, corridor roofs and 2 building facades. The installation area is 13640.6m^2 and the installation capacity is 838.79kWp. Under the current technical conditions, this quantity is insufficient relative to the volume of the park

The photovoltaic panels used on the roof of the park are polycrystalline silicon 1650mm * 1000mm photovoltaic panels. The peak power is 260Wp, a total of 3020 pieces, and the total installed capacity is 785.2kW. The module layout spacing is large, up to 2.14m. Amorphous silicon photovoltaic modules are used on the corridor and the elevation of the Fourth Research Institute, with an installed capacity of 53.59kW. At present, there are 14 inverters, including 100kW*4, 50KW*7, 30kW*2 and 20kw*1 sets (Table.1). Today, these devices have reached the service life that should be updated.

Table 1. Current Situation of Photovoltaic Equipment

Name	Equipment	Quantity	Capacity
PV modules	Polysilicon 260Wp	3020	785.2kW
	Amorphous silicon	411	53.59kW
Inverter	100kW	4	-
	50kW	7	-
	30kW	2	-
	20kW	1	

2.2Existing electrical system and energy storage system in the park

Each building adopts block power generation and centralized grid connected mode. Each photovoltaic power generation unit is composed of photovoltaic modules, DC combiner box, DC distribution cabinet, inverter and photovoltaic grid connected low-voltage cabinet. The inverter of each workshop is connected to the photovoltaic grid connected low-voltage cabinet according to the capacity planning, and is connected to the 380V low-voltage system on the user side through the photovoltaic grid connected low-voltage cabinet.

Photovoltaic energy storage system is constructed in the project, which consists of a group of 50KW×The 4H lead-acid battery is composed of energy storage and connected to the microgrid of the public service building. The photovoltaic system and the energy storage system form a small energy network to stabilize the power fluctuation, cut the peak and fill the valley. In case of power grid failure, it can relay the lighting load of the public service building to maximize the power supply time.

The tubular colloidal lead-acid battery energy storage system is composed of 2v400ah high-performance tubular colloidal battery cells in series. The lead-acid energy storage system battery adopts the bracket arrangement. 250*2v400ah batteries are divided into two brackets, each bracket has two layers, each layer has two columns, and each column has 30 batteries.

2.3Current situation of solar water heating system

At present, solar energy is used as the central hot water system project for preheating heat source. The roof collector covers an area of 1472 square meters. The hot water supply and return temperature is 60 ℃ / 50 ℃. The trough solar collector is installed on the roof of R & D building #10. The collector obtains energy from sunlight. When the solar air conditioning system is not started, the solar collector exchanges heat with the thermal insulation domestic hot water tank through oil-water heat exchanger. The system adopts the solar two-tubes heat exchanger for heat supply and the air-source heat pump unit in the non-transition season of the system.

2.4Current situation of monitoring and control system

The local monitoring system is divided into two layers: system layer and equipment layer. 100m optical fiber Ethernet is used as the communication network and star network structure is adopted. The system layer mainly realizes the functions of real-time data acquisition and communication with the comprehensive energy regulation system of green energy network in the park. Data is obtained from the power regulation system, battery system, distribution system through subsystem including battery capacity, line status, current, active power, reactive power, power coefficient, and mean.

2.5 Target analysis of photovoltaic system renewal

According to the above analysis park, the energy storage system and *solar water heating* system in the park can be maintained for the time being. The performance of the photovoltaic system has more room for improvement. The technologies and products required for the renewal of the photovoltaic system should be the latest, have the highest economy, maximize the use of the park space, and contribute to the direct increase of the proportion of renewable energy in the park. The upgraded photovoltaic system is conducive to the establishment of a zero carbon park and can be profitable.

3. APPLICATION AND EFFECT ANALYSIS OF UPDATE STRATEGY

After the above analysis of the site and the literature, this paper proposes the photovoltaic system upgrading strategy of the park, which is carried out from three aspects: expanding photovoltaic area, upgrading product equipment and improving monitoring management, including 8 upgrading measures (Fig.1). They involve the exploration and Realization of photovoltaic physical potential, geographical potential and technical potential of the park. [14]

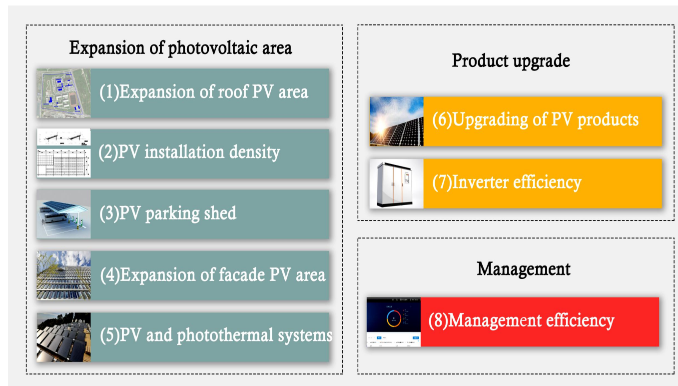

Fig. 1. Park PV upgrade strategy framework

3.1 Expansion of roof photovoltaic capacity

Expanding the roof installation area is the most direct way to increase the photovoltaic power generation. As can be seen from the satellite map and the general plan of the park, including the two temporary buildings in the southeast corner of the park, there is still a part of the roof that can expand the space for deploying photovoltaic modules. The available photovoltaic expansion area can be obtained by combining the solar radiation analysis map and the plan. According to the calculation, the total area that can be expanded is 5845m^2.

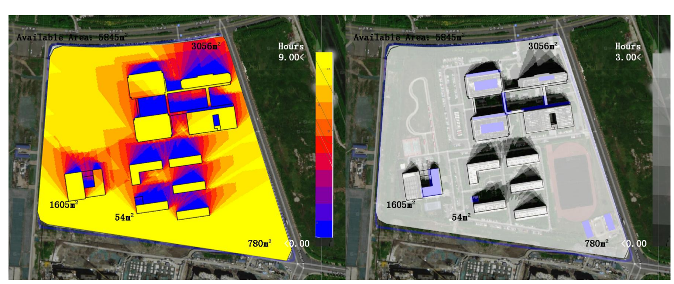

Fig. 2. The available PV expansion area analysis(a.Sunshine duration analysis. b. available area analysis)

3.2 Improvement of installation density of photovoltaic modules

Increasing the installation density of photovoltaic modules in the park is conducive to making full use of the roof area and improving the photovoltaic output efficiency. Some studies show that although the annual solar radiation received by the inclined plane is less when the installation inclination of modules is lower than the optimal inclination, the installed capacity of photovoltaic array will increase under the same floor area. [15]In addition, a new and efficient photovoltaic module - double-sided photovoltaic module has emerged in the market. In order to ensure the light intensity on the back, the installation height and inclination of the module also have specific requirements. When the photovoltaic panels are arranged with the previous "best installation inclination", the power generation efficiency of the double-sided photovoltaic module cannot be brought into full play.

The existing photovoltaic array layout spacing in the park is up to 1.54m. At present, the size of photovoltaic modules with high conversion efficiency in the market is generally about 2200mm * 1105mm. After considering the requirements of module efficiency, module spacing, front and rear shielding, total power generation area and space under double-sided photovoltaic panels, it is determined to adjust the module inclination angle to 11° (even though the original array has considered this factor, the value of 22° is used, and the "optimal installation inclination" of 30° is not used). After calculation, the photovoltaic installation area in the park increases by 3011m^2 after the installation density is increased.

3.3 Deployment of photovoltaic parking shed

In recent years, with the continuous development of science and technology, new energy vehicles have been continuously promoted and used, and distributed charging devices are in short supply. Charging electric vehicles after distributed photovoltaic power generation can just avoid its unstable disadvantages, and make new energy vehicles use real "green electricity". This measure can also reduce the sun shining on cars, reduce the use of air conditioning and further save energy. The industrial park is usually located in the suburbs of cities, with more commuter vehicles and more parking spaces for buses and small cars on the ground, which is suitable for the installation of photovoltaic parking sheds.

In the State Grid customer service park, according to the satellite map image and field investigation, the location and quantity of parking spaces are corrected. The size of each small car parking space is 2800mm * 6000mm, and the size of each bus parking space is 3500mm * 12400mm. Considering that there are support columns and charging piles under the parking shed to occupy a certain area, and considering shadow shielding, the photovoltaic parking shed for small vehicles is set as 7200mm wide, 3000mm high at the cornice end and 2100mm high at the rear end; the photovoltaic parking shed for buses is set as 13500mm wide, 4800mm high at the cornice end and 4200mm high at the rear end. The areas where the radiation intensity and duration do not meet the requirements are removed, the total PV installable area of PV parking shed for small cars and buses is 9982m^2.

3.4 Expansion of the facade PV area

Photovoltaic modules have good prospects and energy-saving potential in the application of building facade. The academic community once thought that the temperature coefficient of thin-film modules is lower and more suitable for installation in building facade, but today there are more facade photovoltaic building materials and photovoltaic windows with different materials and higher efficiency. When photovoltaic windows are applied, the structure and lighting of photovoltaic external windows should be optimized on the premise of ensuring the lighting demand. At the same time, more attention should be paid to the thermal performance, structural reliability, electrical safety and fire resistance of photovoltaic modules.

At present, only the #4 R & D building and some corridor facades in the park are equipped with amorphous silicon photovoltaic modules with an installed capacity of 53.59kW. After shadow shielding and solar radiation analysis, it is determined that the south facades of #1, #3, #7, #8 and #10 R & D buildings have strong photovoltaic power generation potential. Therefore, it is recommended to deploy photovoltaic building materials on the south facades of these five buildings. It is calculated that the facade can expand the photovoltaic area by 5120m^2.

3.5The combination of the PV and PT（photothermal）in the park

According to the hot water demand, combined photovoltaic with photothermal, PVT module is used to replace the original photothermal module. PVT combines solar PV module with t collector to recover the heat at the back of the panel through the collector, which not only obtains additional heat energy, but also reduces the PV temperature and improves the photoelectric conversion efficiency, so as to improve the comprehensive energy utilization efficiency of the system.

At present, a solar roof collector with an area of about 1472 square meters is installed on the roof of the floor of the #10 R & D building in the park. The water supply and return temperature of hot water is 60 ℃ / 50 ℃. Replacing the solar collector with PVT module can generate 410MWh DC power every year while providing domestic hot water.

3.6Upgrade of equipment and management

The photovoltaic panels produced about five years ago are small in size, mainly polysilicon modules, and have low power generation efficiency. In each link of photovoltaic area expansion in the above parks, it is planned to use monocrystalline silicon photovoltaic components with current photoelectric conversion efficiency of more than 20% and inverters with inverter efficiency of more than 98.5% and suitable for the electrical system of the park.

Combine the existing control platform with the current new communication, control and display methods and equipment to fully improve its control and operation efficiency. On the basis of the original intelligent control center and the operation control platform of green composite energy network, large screen can be further used in combination with app. This will help to complete the functions of centralized management of operation indicators, historical data visualization, report subscription, real-time alarm push, one-screen display management site, operation and maintenance personnel and status, intelligent IV diagnostic power station and so on.

4. INVESTMENT AND RETURN ANALYSIS

After determining the PV usable area that each PV upgrade measure can increase, the PVSYST is used for further quantitative analysis. In the PVSYST 7.2 system, the meteorological data is selected as Tianjin/Tientsi_MN80.SIT-Meteonorm8.0(Fig.3). The PV usable area, PV module brand number, PV inverter brand model, regional meteorological parameters and other information are set up, and then the serial number of the group is adjusted.Calculate the output power generation, capital investment return and carbon emission reduction, and generate analysis table and analysis diagram at the same time.

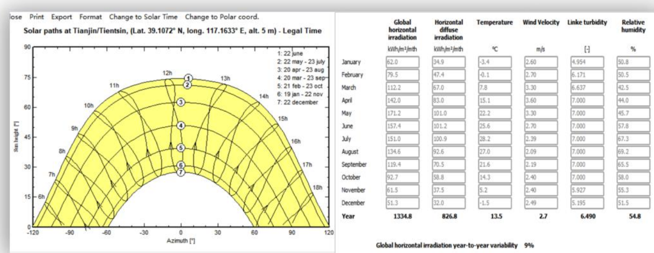

Fig. 3. Meteorological data of Tianjin

Table 2. PV potential analysis results

Measures	Area(m^2)	Capacity (kWp)	Module selection	Power generation (MWh·a)	Cost(RMB million yuan)	Carbon emission reduction(t·a)
Rooftop PV expansion	5845	1235	Trina Solar tsm-de20	1640	2.07	31632.5
PV parking shed	9982	2040	Yingli JSM GG 144cell SC d-sided	3019	4.45	61392
Inclination adjustment of PV panels	3011	1518	Trina Solar tsm-de20	2074	2.9	41632.5
Increasing of facade PV area	5120	868	Kongming 60cell/brick	1050	2.8	16573
Update PV inverter	\	\	Sunshine power sg1500ud	Change with power generation		

As shown in Table 2, the time cycle of realizing all upgrade schemes is long and considerable capital investment. The park can give targeted priority to one or more measures by considering the target requirements of the renewable energy substitution rate, the convenience and efficiency of the measures, and the funding situation.

5. CONCLUSION

The existing integrated energy parks have the demand and space for renewable energy renewal.This paper studies the Grid Customer service park in Tianjin, and the results show that the PV system upgrading strategy should be implemented from three aspects: expanding the photovoltaic area, upgrading the products and equipment, and improving the monitoring and management. These measures make the park's renewable energy output increased, more energy efficient and can enhance its demonstration significance.

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