

The Integrated Design of Photovoltaic Power Generation and Clean Heating

Chen-Xiao MA¹, Fan XIAO¹ and Shi-Lin SUN¹

¹Northeast Electric Power University, Jilin 132012 China

Keywords: Photovoltaic power, clean heating

Abstract. With the rapid development of clean energy substitution, problems such as the difficulty of pv absorption, the large investment in clean heating power grid transformation and the utilization rate of equipment appear. In this paper, the design of photovoltaic and clean heating, and the design of the integrated solution, and by providing the power of the solar power plant in the surrounding areas, is to maximize the use of clean energy, minimize the power grid investment, and minimize the impact of the power grid. After the feasibility and economy demonstration, it has a great promotion value.

Introduction

With the rapid development of clean energy substitution, problems such as the difficulty of pv absorption, the large investment in clean heating power grid transformation and the utilization rate of equipment appear. In this paper, the design of photovoltaic and clean heating, and the design of the integrated solution, and by providing the power of the solar power plant in the surrounding areas, is to maximize the use of clean energy, minimize the power grid investment, and minimize the impact of the power grid. It is prove by feasibility and economy that it has great popularization value.

In recent years, photovoltaic power generation, especially distributed photovoltaic power generation, has developed rapidly. By the end of 2016, China's pv installed capacity has reached 77.42 million kilowatts, ranking the first in the world. With the explosive growth of photovoltaic power generation, due to the limitation of the capacity of the upper transformer and the power load of the power grid, the problems of power generation absorption and delivery become the bottleneck of development day by day. On the other hand, "coal to electricity" heating has made rapid progress. Taking Beijing as an example, in 2016, a total of 574 villages and 198,000 households of coal were converted to electric heating and in 2007, all "coal free" heating in all plains villages continued to be implemented. Due to the extensive use of electric boilers, the capacity of some coal to electricity's equipment in power grid limited, so the power grid must be accompanied by the power equipment capacity enhancement transformation, resulting in huge investment in power grid transformation. However, the annual heating time is only about 4 months. In the non-heating season, a large number of distribution transformers and lines are idle, leading to a large waste of equipment resources. In recent years, domestic scholars have conducted extensive research on the photovoltaic absorption mode, the utilization of electric energy and solar energy and other clean energy heating modes, but there have been few studies on the application of photovoltaic power generation to clean heating, and no studies on the collaborative design of photovoltaic power generation and clean heating. It is necessary to establish a new mode of energy interconnection that is complementary and synergistically driven by clean energy and clean heating, so as to provide theoretical basis and practical basis for the sustainable development of clean energy substitution.

Photovoltaic Power Generation and Clean Integration Design

Integrated Design Scheme of Photovoltaic Absorption and "Coal to Electricity" Heating

The integrated design scheme of photovoltaic absorption and "coal to electricity" heating is aimed at maximizing the consumption of clean energy, minimizing the emission of heating pollution and minimizing the waste of power grid resources, Photovoltaic power generation is directly used for

heating local electric boilers, so as to consume the surplus electricity on power grid and reduce the incidence of light rejection; Electric boiler power consumption is obtained locally, reducing the investment cost of electricity network.

In view of that describe scheme, a new village construction community in heze, Shandong is selected to carry out the construction of distribute photovoltaic power generation projects, and to implement electric boiler heating reform at the same time. There are about 500 households in the community, with a roof area of 100 square meters per household

Overall System Design

One set of photovoltaic equipment is installed on the roof of the community, one 10kv confluence station is built, and one set of heating equipment is installed in the community for storing thermal power boilers. The photovoltaic module is connected to the 10kV confluence station by boosting transformer and changing the voltage, the heating circuit is formed from the bus outlet of the confluence station to the equipment of the heat storage electric boiler. Meanwhile, the bus bar is connected to the 10kV space of the public substation through 10kV dedicated line, which constitutes the photovoltaic power grid and the standby power supply circuit of the electric boiler. The wiring diagram is shown below.

The Design of Photovoltaic Power Station

According to the distribution map of solar energy resources in China, Heze is divided into the third region, which means the annual sunshine hours are between 2200 and 3000 hours, and the total annual radiation amount is 1405KW/m².The total pv capacity that can be constructed locally can be calculated as follows:

$$P = ps \quad (1)$$

P per square installation capacity; S for the total area of the roof

By installing 0.1 KW per square meter, considering the total area of the roof is 50,000 square meters, and with the proper consideration of the public area of 10,000 square meters, it would be able to calculate the total capacity of the project

$$P = 0.1 \times (10000 + 50000) = 6000KW$$

This project has a total of 270W photovoltaic modules, 22300, 50kW inverter 120, total installed capacity of 6000KW, the photovoltaic power station can be connected to the grid by sub-regional power generation and centralized connection.

The photovoltaic power station is divided into six generating units, each of which is equipped with a 1000kVA booster transformer. After 6 transformers have been boosted to 10kV, they will be connected to 10kV collection switch station via the collector line, and then connected to the substation by the newly built 1-circuit special line. The gathering and switching stations are respectively equipped with high voltage inlet switch and variable voltage equipment, and equipped with corresponding protection, automation and electric energy measuring devices. The equipment list is as follows:

Design of Electric Heating

Due to the residents in a community to gather, choose solid regenerative boiler, 10 kv voltage. When the sunlight is sufficient, and the pv output is large from 8 o'clock to 16 o'clock, the pv power generation is used for heating and heat storage. When the sunshine gradually disappears after 16 o'clock, the heat storage is released for heating. In continuous cloudy and snowy weather, during the low load of the power grid from 23 o'clock to 7 o'clock in the morning, the pv grid-connected contact line is used for heating and heat storage. During the peak load from 7 o'clock to 23 o'clock, heat storage is released for heating.

Table 1 Device List

device name	Equipment model	The unit price	amount	Total (RMB 10,000)
Solid heat storage boiler	Reze 10kv solid heat storage boiler	850/kw	3400	289
heat supply pipeline	200mm	69.996	3200	22.4
				311.4

Analysis of Differences with Traditional Schemes

In the design part of the photovoltaic power station, the traditional pv is fully online, and there is no difference between the two schemes. In the boiler heating design, the conventional heating power is connected to the public power grid. And at present the price of electricity is the lowest price made by the power supply department (23:00 to 7:00 next day). On the choice of boiler also uses heat storage boiler. Since the power trough is 8 hours, there is no difference between the two schemes. This scheme does not need to be reformed in the design of power grid reconstruction. The traditional solution requires the power supply equipment that does not meet the requirement of the load to be modified.

After the heating boiler is connected to the public distribution network, the operating current of power supply distribution network wires is calculated according to the following formula.

$$I_e = I_1 + I_b \quad (2)$$

Among them: I_1 is rated current of boiler, i is the minimum rated current of each household, b for the total number of households.

$$I_1 = P / \sqrt{3}U = 3400 / (1.732 \times 10) = 196A \quad (4)$$

According to the design specifications, the average household capacity in rural area B is no less than 3KW, lead to a minimum rated current of that household

$$i = P / \sqrt{3}U = 3400 / (1.732 \times 10) = 0.17A \quad (5)$$

Thereby calculating the wire running current $I_e = I_1 + ib = 196 + 0.17 \times 500 = 281A$

The original 10kV line was replaced by JKLGYJ-95 wire, the allowable current is 300A. Calculated at 4 km, and the fund amounted to 800000 yuan.

The Feasibility and Economy Analysis

The Feasibility Analysis

The Feasibility of Equipment Selection

For the photovoltaic power generation related equipment, with the large number of photovoltaic power stations put into operation in recent years, the technology has been quite mature, and there are many equipment manufacturers. Solid storage technology has grown rapidly in recent years, technology is becoming more sophisticated, the efficiency of the heat storage system reaches over 2500MJ/m³. the thermal efficiency is over 90%, it can supply heat at full load for 24 hour or more, and fully satisfy the heating requirement.

Operational Feasibility//The Feasibility of Operation

Comparing the winter power generation of photovoltaic power station and boiler power consumption, the power generation of photovoltaic power station can be estimated by the following formula:

$$Q = PSt\eta \tag{6}$$

Among them P is the monthly average amount of radiation

S for photovoltaic (pv) receiving area

T is the annual peak sunshine hours of inclined plane

η is the efficiency of the photovoltaic system

The annual peak hours of sunlight can be calculated from the average level of radiation data. Therefore, the estimated pv capacity of 6000KW photovoltaic power station in the winter of November, December, January, February and march is as follows:

Table 2 Power Supply Situation

Month	Average monthly radiation(KWh/m2)	Monthly power generation output (Million kilowatt hour)
November	0.15	81.6
December	0.14	76.2
January	0.15	81.6
February	0.15	81.6
march	0.17	92.5

The monthly electricity consumption of the boiler is estimated by 30 days per month $Q_2 = 0.312 \times 8 \times 30 = 749000$ KWh

As can be seen from the above analysis, under normal circumstances, the power generation can meet the boiler power supply needs. Under abnormal conditions, such as rainy days and equipment damage, power can be supplied from the power grid through the grid-connected contact line.

The Economy Analysis

By using the static analysis method, this scheme is compared with the traditional scheme in terms of cost investment economy and profits of photovoltaic enterprises in subsequent operation.

Cost-efficient Analysis

At present, the cost of photovoltaic power generation, heating renovation project involving the investor has three, respectively for the photovoltaic enterprise, government + users, power supply company. The photovoltaic enterprises are in charge of the construction of photovoltaic power stations, the government and users (as a main body) are responsible for the construction of electric boilers and other heating facilities, and the power supply companies are responsible for the modification of the power grid resulting from this. Its input cost are analyzed respectively as follow:

Since the design of photovoltaic power generation and heating design are the same, the cost of photovoltaic power generation enterprise is the same, amounting to 360.06 million yuan. The cost of government and users is the same, at 3.114 million yuan.

The power supply company's investment in this scheme is zero. In the traditional scheme, 800 thousand yuan should be invested to modify/transform/upgrade the distribution network line. If 35kV and above equipment transformation is taken into consideration, the investment amount is even greater. Therefore, we can draw the conclusion that the cost input of this scheme is smaller than that of the traditional scheme and the economic benefits are obvious.

The Economic Analysis of Photovoltaic Power Station

The analysis of the model that all the electric is delivered to the power grid

The annual output of distributed photovoltaic power generation system is

$$Q = \frac{H_t}{H} PC\eta \quad (7)$$

Among them: Q is the annual photovoltaic power generation kW h; H_t is the annual amount of solar radiation kW · h / m² ; H is the standard solar radiation intensity kW /m² ;P for photovoltaic power generation systems installed capacity kW;C for the radiation coefficient of the inclined pv module;η is the comprehensive influence coefficient of power generation system. In heze, H_t is 1405 kW h / m², C equal 1. 05~1. 15, and C = 1. 1.For a grid-connected power generation system, η is 80%.According to formula (3), the annual power generation of the system is 7418400 kW h, Except for the eight days before and after the Spring Festival light power 224000 kW · h, power generating capacity is 7194400 kW ·h.According to the online electricity price of 0.65 yuan/degree, and the power grid loss cost of 1000kW h is 500 yuan.Total annual income is 7194400×0.65-719.44×500=4616640yuan,is equal to about 4.617 million yuan.

Static payback time=initial investment annual net profit is 3600.6÷461.7=8years

The analysis of the model that part of the electric is delivered to the power grid

This scheme adopts the model that part of the electric is delivered to the power grid after heating; the total revenue is the sum of heating revenue and power grid electricity revenue. Among them:

$$\begin{aligned} \text{Photovoltaic heating revenue} &= \text{Heating power} \times \text{Heating time} \times \text{State subsidies} \\ &+ \text{Heating fee} + \text{Government heating subsidy} \end{aligned}$$

According to the policy requirement, the standard of heating fee should be the same as the cost of farmers' own coal heating. According to this calculation, The heating efficiency of traditional coal burning is about 80%, converting by 10,000 kilowatt-hours of electricity is equivalent to 1.228 tons of standard coal, Each household uses 0.843 tons of standard coal during the 110-day heating period, referring to the price of anthracite, 1261.7 yuan/ton, The annual heating expenditure of farmers is 1063 yuan, and maintain the price the same calculation, The revenue of photovoltaic enterprises is 531,500 yuan.

After the implementation of the local heating scheme, the photovoltaic enterprises can receive the photovoltaic power generation subsidy of 0.42 yuan/KWH.In the 110-day heating season, about $W=Pt=3120*8*110= 2.7456$ million kilowatt-hours are needed for electricity consumption,and the state subsidies which are obtainable is1153152 yuan The income of heating season is 1684,652 yuan, In the non-heating season and the heating season, the total amount of electricity generated from the power grid is 7418400-2745600=4672800 kW h. According to the electricity price of 0.65 yuan/degree, the income of the surplus electricity amounts to 303,7320 yuan.The total revenue is 4.722 million yuan.

static payback time is 3600.6÷472.2=7.6years

It can be concluded that: This scheme increased net income by 105,000 yuan per year compared with the traditional scheme.Static payback time shortened nearly 5 months. With the large-scale photovoltaic operation, the discharge rate will increase year by year; the economics of the programme will become more apparent.

Conclusions and Prospects

This paper innovatively proposes the co-promotion strategy of photovoltaic power generation and "coal to electricity" heating.through the integrated design of photovoltaic power generation and clean heating, solves the disadvantages such as difficulty in absorbing solar energy and low utilization rate of equipment caused by the separate implementation of two previous energy-saving and emission reduction projects ,and has found a new mode of energy interconnection featuring clean energy, clean heating, complementary and coordinated promotion, provides a theoretical basis and practical basis for the sustainable development of clean energy substitution.Through feasibility and economy demonstration, it has great value of promotion.

Photovoltaic power generation and "coal to electricity" clean heating are bound to show a rapid development in the next few years. In the future, the design scheme can be further studied. In the non-heating season, photovoltaic power generation is used for power supply in air conditioning refrigeration, life, agricultural greenhouses and other facilities.

References

- [1] Zhang yifei. Study on cost-effectiveness of photovoltaic power generation project [D]: Heilongjiang bayi agricultural university, 2017.
- [2] Shu haijing. Potential analysis of wind and solar power resources in Jinan [D]: Shandong University, 2005.
- [3] Wang tiezhu. Modeling and simulation research on large-scale energy storage system to improve the photovoltaic absorption capacity of power grid [D]: north China University of electric power (Beijing), 2017.
- [4] He huimin, wang haiyan, ren jie, etc. Feasibility study on replacing winter heating with electric energy by wind power discard [J]. North China power technology, 2016.
- [5] Lin changqin, wang Dan, Lin shunkang. Application of solar energy heating technology in taizhou region [J]. Shanxi architecture, 2015.
- [6] Chen jichen. Study on cost management of a rural "coal to electricity" project in a certain area of Beijing [D]: north China university of electric power (Beijing), 2017.
- [7] Cong jing, ju zhenhe, lei caijuan. Housing insulation assessment and winter heating and solar energy utilization in Beijing [J]. Solar energy, 2015.
- [8] Wei xiaoyu, Chen yunhui, yuan zhiqiang, etc. Application of heat storage system in solving photovoltaic absorption problems [J]. Power supply, 2017.
- [9] Shao hanqiao etc. Analysis on the economics and policies of distributed photovoltaic power generation. Electric power construction, vol. 35, no. 7