Conference Proceedings

EuroSun 2014
Aix-les-Bains (France), 16 – 19 September 2014

Design and Benefits Analysis of Building Integrated Photovoltaic Project

Chunxia Jia[1], Airong Feng Zhong Li Aisong Li and Zongjiang Liu

[1] China Academy of Building Research, Beijing (China)

Abstract

A public building integrated photovoltaic project in Yinchuan is introduced in this paper. In the BIPV project the polycrystalline cells are installed on the roof, which provide lighting electricity for the building. With the help of building simulation software, the available vacant area is analyzed. The total installed capacity is 100 KW; the annual generation capacity of the photovoltaic project is 115081 KWh. It has obvious environmental benefits to utilize renewable energy. In this project utilization of PV system can replace 38.21 tons of standard coal; reduce 102.65 tons of carbon dioxide emissions, 0.77 tons of sulfur dioxide, 0.06 tons of nitrogen oxide and 0.39 tons of dust. However compared with the traditional municipal power supply, the cost effectiveness ratio of the PV power supply system is 0.23 USD/KWh. According to the technical and economic analysis, in order to promote the wide application of photovoltaic technology, it needs certain policies and financial allowance.

Key-words: building integrated photovoltaic; technical and economic analysis; environmental benefits

1. Introduction

As the energy crisis's influence on human development has become increasingly obvious, the countries in the world began to attach great importance to the development of renewable energy. Yinchuan located in the northwest of China has a temperate continental climate and rich solar energy with annually 3011 hours of sunshine and 6030 MJ/(m²a) solar irradiation on a horizontal plane (corresponding to 1675 kWh/(m²a)).However there are severe problem of energy shortage in rural and pastoral areas. If through erecting the electric grid to provide lighting and cultural life of electricity, the capital investment is very expensive, and it is not easy to manage and maintain electric system. Therefore it is richly endowed by nature to promote photovoltaic power generation technology in northwest of China. A public building integrated photovoltaic project in Yinchuan is introduced in this paper. The design of building integrated photovoltaic project was optimization by ecotect software. Furthermore the conservation of fossil energy and reducing pollutant emission of the photoelectric building was calculated.

2. Design of Building integrated photovoltaics engineering

2.1. Climatic conditions

Yinchuan is belong to Ningxia province located in northwest of china. Yinchuan city is temperature continental climate with distinctive four seasons. The monthly dry bulb temperature statistics are listed in Fig.1. The annual average temperature is 8℃and there is obvious temperature difference between day and night. Above outdoor climate parameters is from compiled data of 193 cities in 20 years by Tsinghua University and the China Meteorological Administration [1].

The annual solar radiation intensity statistics of Yinchuan are shown in Fig.2. Yinchuan's solar radiation and sunshine time are one of china's most abundant regions. Its territory is vast; however the density of population is small. So the application potential for solar energy technology is obvious in Yinchuan city.

doi:10.18086/eurosun.2014.02.02 Available at http://proceedings.ises.org

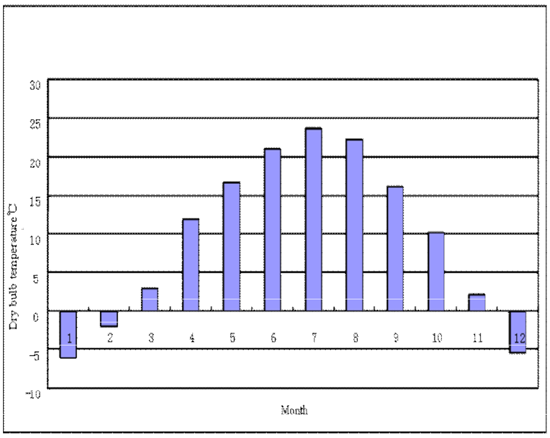

Figure1. Chart of monthly mean dry bulb temperature

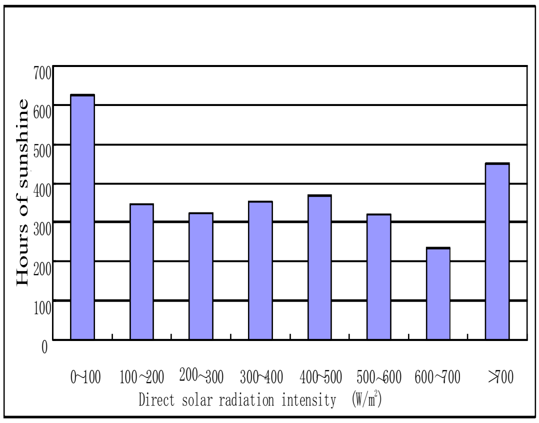

Figure2. Chart of annual solar radiation intensity

2.2. Power load of Demonstration building

The structure of the demonstration building is simple. Its roof is flat and wide, suitable for large-scale installation of photovoltaic panels. Photovoltaic power generation is used to meet the electricity demand of demonstration building. The main rooms of this building include exhibition hall, multi-function hall, lounge, bathroom, staircase and warehouse. The power loads are mainly from lighting electricity.

$$Q_{AC} = W \times A \qquad \text{(eq. 1)}$$

$$Q_{DC} = \frac{Q_{AC}}{0.95} \qquad \text{(eq. 2)}$$

$$Q_d = Q_{DC} \times H \qquad \text{(eq. 3)}$$

Where, Q_{AC} , Q_{DC} and Qd is alternating current load, direct current load and daily power load respectivly. Q_{AC} is equal to lighting power density (W) multiplied by room areas(A). H is the daily lighting hours.

The calculation result is listed in the Tab.1.Some important parameters can be calculated by means of value in Tab.1. The design max DC load of the building is 31.08 KW; the annual energy consumption is the 111597.52 KWh.

Tab. 1: Calculation result of light power consumption

	Exhibition hall	**Multi-function hall**	**lounge**	**bathroom**	**Stairwells**	**Warehouses**
Lighting Power Density (W/m^2)	20.00	18.00	10.00	10.00	5.00	5.00
Area(m^2)	1091.21	224.99	195.67	62.38	94.28	120.14
AC load(W)	21824.10	4049.73	1956.73	623.84	471.40	600.69
DC load(W)	22972.74	4262.87	2059.71	656.67	496.21	632.31
Frequency(H)	10.00	10.00	10.00	10.00	10.00	2.00
Daily load(KWh)	229.73	42.63	20.60	6.57	4.96	1.26

2.2. Design of photovoltaics system

The type PV integrated with building is various [2]. To sum up, it may be classified as two major types. One type, the packaged PV modules are installed on the roof of the building, and the building, playing a supporting role, can be viewed as a carrier for PV arrays. The other type, PV modules are not only power generating facilities, but also meet some functional requirements as building units. In the BIPV project, PV modules will be installed on the roof.Although there are no other tall building around the project construction, part of the roof height is not consistent. In order to confirm the installation areas of the photovoltaics panels, it need to analysis the roof shadow. First the building plane model is built by CAD, then it is imported into Skechup soft to establish three-dimensional model shown in Fig.3, and finally Ecotect platform is used to simulate the roof shadow.

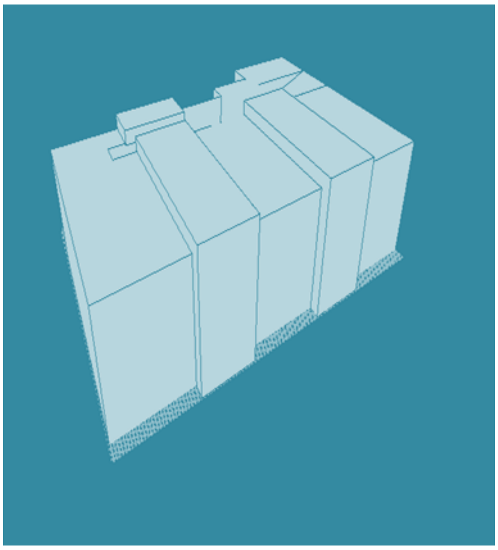

Figure3. Chart of building model

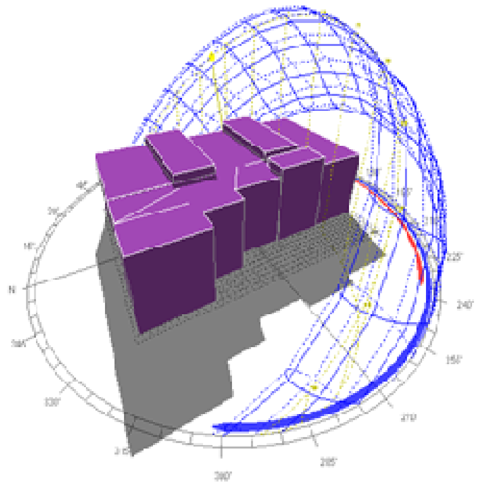

Figure4. Chart of shadow simulation

With the help of building simulation software, the shadow of building roof is shown in Fig.4. According to the result, the available vacant areas are about 660 m^2 to install the photovoltaics panels. Previous engineering practice shows that the best installation angle of the solar battery array refer approximately to the local latitude in general. By means of the software simulation the cumulative solar radiation amounts are maximum when the installation angle is 30 °. However taking into account no occlusion around the buildings the photovoltaics panels are installed on the roof of the demonstration building horizontally. This type of installation is easier to construct. The vertical distance between arrays is confirmed according as the solar cell arrays are not blocked at 9:00-17:00 in the solstice. Whereas considering the actual operating temperature, the pressure drops loss of transmission line, uniform radiation and photovoltaic module's surface dust so on, the actual efficiency of photovoltaic power generation is 0.75.

3. Technical and Economic Analysis

The generated power of photovoltaic panels is calculated according to reference [3].The calculated result of the generated electrical energy monthly is presented in Fig. 5. It shows that generation from April to August is higher than in the other months. And the maximal generation 6.06 KWh/m^2.d occurs in May. The daily average generation power is 4.38 KWh/m^2. The annual generation capacity of the photovoltaic project is 115081 KWh. It can meet the lighting loads of the demonstration building.

The PV system mainly includes Polycrystalline silicon modules, inverters and monitoring system so on. There are 400 pieces of silicon PV modules installed in this project. The size of photovoltaic panels is 1650 mm × 990 mm each. The component and their investments of the PV system are listed in the Table 2. The total installed capacity is 100 KWp and the total investments are 0.65 million USD.

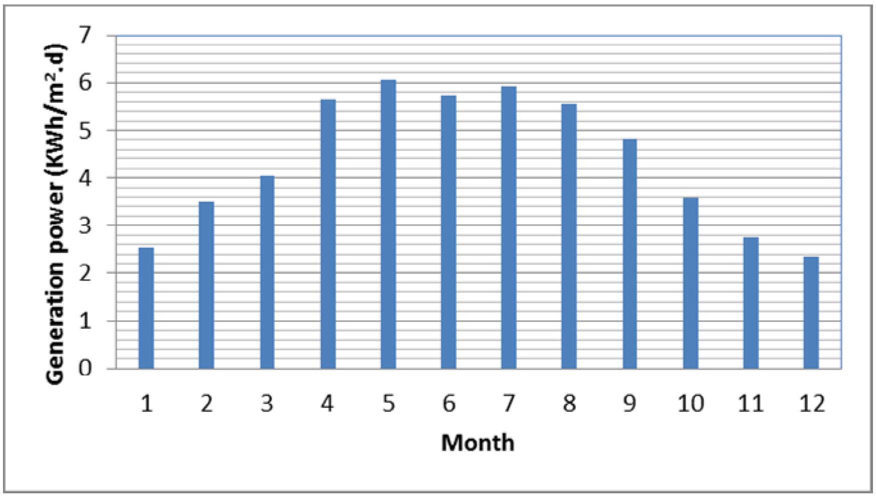

Figure5. Daily generation of PV system

Tab. 2: Investment of PV system

	Equipment	Quantity	Investment	
			Unit-price USD	Total price USD
1	Photovoltaics system			
	Polycrystalline silicon PV modules （250W/piece）	400	650	260163
	Fixed bracket			48780
	Inverter	2	8130	16260
	Line collection box of direct current	10	813	8130
	Cabinet of grid alternating current	1	8130	8130
	Cable			24390
	Other accessories			32520
2	Monitoring system			97561
3	High voltage equipment			48781
4	Basic fee			32520
5	Iinstallation fee			48781
6	Transportation fee			24390
7	Total			650406

If considering cost and electricity of the PV system, 2877025 Kilowatt-hours will be generated in 25 years and its cost effectiveness ratio is 0.23 USD/KWh in life period. Compared with the public electricity price 0.12 USD/KWh, the prices of photovoltaic power generation is still higher. The main reason for high cost effectiveness ratio is more investments but shorter life. In view of this, some policy and strong economic support on PV projects are appropriate, if so, the PV systems will be widely used.

4. Social Benefit and Environmental Impact

The application and popularization of renewable energy is important. The development and utilization of renewable energy will save and replace large amounts of fossil energy, lower pollutions and greenhouse gases obviously, and promote the harmonious development between human and nature. According to reference [4], every 10,000 KWh power generated by PV systems means saving 3.6 tons of standard coal consumption, reducing 9.432 tons of CO_2, 0.05868 tons of SO_2, 0.01728 tons of NO_x, 0.02304 tons of dust. In this project, PV systems power is, 2877025 KWh, and the environmental consequences are shown in the Table 3.

Table.3 Analysis of environmental effect

	Emission reductions	Consequences of emission reduction	
	Ton	USD/ton	10,000 USD
Saving of standard coal consumption	9.268293	89.4	9.3
Reduction of CO_2	3.577236	13.0	3.6
Reduction of SO_2	0.325203	204.9	0.3
Reduction of NO_x	0.162602	325.2	0.2
Reduction of dust	0.065041	89.4	0.1
social benefit analysis of this project（in 25 years）			13.5

5. Conclusions

The economic and technical analysis of BIPV project shows the initial investment of the PV system can't be retrieved during the whole life period, in spite of the operating cost is almost zero. The main reasons are that the power efficiency of PV is too lower, and the cost of PV cell is too expensive. So it needs the support of the policy and finance allowance. Although there is no obvious economic benefit, the BIPV project still plays a good demonstration role.

Acknowledgement

The paper was supported by a Project of the National Twelfth-Five Year Research Program of China (Project No. 2011BAJ08B08).

Reference

[1] Meteorological Reference Room of China Meteorological Administration, Building Science and Technology Department of Tsinghua University: Spacial Meteorological Dataset for Indoor Thermal Environment Analysis in China (China Architecture & Building Press, China 2005).

[2] Wang, S.C., China Construction (Solar & Renewable Energy Sources) Vol. 01(2007), pp.50

[3] Chen, J., Mechanization In Rural & Pastoral Areas Vol. 02 (2006), pp. 27

[4] Zhao, H.L., Verification Reference Manual on Emission Reduction of Main Pollutants (China Environmental Science Press, 2008)