Contrastive Observation of Solar Thermal and Photovoltaic Resource

BIAN Zeqiang, LYU Wenhua, CHONG Wei

(*Meteorological Observation Centre*, *China Meteorological Administration*, *Beijing* 100081, *China*)

Abstract: Solar thermal and photovoltaic applications are the most widely used and the most successful way of commercial development in solar energy applications. Observation and assessment of solar thermal and photovoltaic resources are the basis and key of their large-scale development and utilization. Using the observational data carried out from Beijing southern suburbs observation station of China Meteorological Administration in summer of 2009, preliminary solar thermal and photovoltaic resources characteristics for different weather conditions, different angle and different directions are analyzed. The results show that: (1) In sunny, cloudy or rainy weather conditions, both of solar thermal and photovoltaic sensors daily irradiance have consistent change in trend. Solar thermal irradiance is larger than photovoltaic. Under sunny conditions, solar thermal global radiation has about 2.7% higher than the photovoltaic global radiation. Under cloudy weather conditions, solar thermal global radiation has about 3.9% higher than the photovoltaic. Under rainy weather conditions, solar thermal global radiation has about 20% higher than the photovoltaic. (2) For different inclined plane daily global radiation, southern latitude -15 °incline is the maximum and southern vertical surface is the minimum. The order from large to small is southern latitude-15 ° incline, southern latitude incline, southern latitude +15 °incline, horizontal surface and southern vertical surface. Southern latitude -15 °incline global radiation has about 41% higher than the southern vertical surface. (3) For different orientation vertical surface daily global radiation, southern vertical surface is the maximum and western vertical surface is the minimum, which eastern vertical surface is in the middle. Southern vertical surface global radiation has about 20% higher than the western vertical surface.

Key words: Solar Thermal Resource; Photovoltaic Resource; Contrastive Observation

1 Introduction

In recent years, with the growing tension of conventional energy sources and the increasing pressure of global climate change, development of renewable clean energy like solar resource has been recognized unanimously. Solar energy utilization includes solar thermal[1], solar photovoltaic[2], solar photochemical[3], solar biological utilization[4] and other ways of utilization.

The most widely used and commercially successful ones are solar thermal and photovoltaic applications. Solar thermal conversion refers to the conversion of solar into heat by receiving or concentrating solar energy[5]. Photovoltaic conversion refers to the transform of photovoltaic into electrical energy[6].

Solar energy resources development inChina has great potential[7]. The large-scale exploitation and utilization of solar energy resources are meaningful for China to adjust its energy structure and cope with climate change.

There are many ways to utilize solar energy resources, andthe effects of various ways are also different Solar photovoltaic is mainly through the absorption of solar photons to generate electricity, so the main absorption of visible light, spectral range is about 400 to 1100nm[2]; Solar thermal focuses on heat collecting and both direct and scattered radiation can be used, the spectral range is approximately 305 to 2800 nm, the absorption spectral range is wider than photovoltaic[5]. Therefore, the observation and evaluation of solar energy resources for different utilization methods are the premise and the key of solar energy resources development and utilization.

Most solar radiation observation in China ishorizontal global radiation by pyranometer. Solar energy evaluation is mainly about solar thermal resource, so it cannot fully meet the needs of a variety of solar energy resources utilization[8].

In this paper, solar thermal and photovoltaic resources characteristics at different weather conditions, different angle and different directions are analyzed by the observation data in Beijing South Base of China Meteorological Administration.

2 Comparative Observation Test of Solar Thermal and Photovoltaic Resources

2.1 Comparative Observation Test System

In order to research solar energy professional observation methods and obtain better solar thermal and photovoltaic resources assessment, solar energy resources observational tests were carried out by the meteorological observation center of China Meteorological Administration, as shown in Fig. 1.

Observation instruments are installed on the tower with cement base, and the underlying surrounding is covered by the natural grass.

The selection of observation points avoids the shielding of the surrounding buildings, and the visibility factor over the observation points is almost 1. In order to get solar thermal and photovoltaic resources under different weather conditions, solar thermal and photovoltaic resources observational data are compared in three typical weather conditions, namely, clear weather (23rd of August), cloudy weather (24th of August) and rainy weather (25th of August).

Experimental observations include:

Thermal pyranometers with horizontal installation and rotational shading photoelectric pyranometers;

Thermal pyranometer and photoelectric pyranometer with different tilt angle (latitude; latitude + 15°; latitude-15°).

Thermal pyranometer and photoelectric pyranometer with different vertical surface (East, West, South).

The data sampling frequency is 10Hz, automatically generating a set of average values per 10min.

Fig. 1 Observation test structure

2.2 Observation Instrument

Thermalpyranometer takes Hukseflux′s SR11 radiation sensor, as shown in Fig. 3.

Fig. 2 SR11 solar thermal global radiation sensor

The spectral range of the thermal radiometer is 305 nm ~ 2 800 nm, which is close to the spectral range of the solar thermal collectors, the specific performance indexes are shown in Table 1.

Table 1 SR11 solar thermal global radiation sensor technical specifications

SR11 technical specifications	
ISOclassification	Class one
Spectral range	305 ~ 2800 nm
Sensitivity (rated)	15 μV/Wm^{-2}
Temperature range	-40 ~ +80℃
Measure range	0 ~ 2000 Wm^{-2}
Temperature influence	<0.1%/℃
Traceability	WRR

Photoelectricpyranometer takes Li-Cor′s LI200SB radiation sensor, as shown in Fig. 3

Fig. 3 LI200SB photovoltaic global radiation sensor

The spectral range of the photoelectric radiometer (400 ~ 1100nm) is close to that of the solar panel. The response time of photoelectric radiation meter (typically less than 10s) is much smaller compared to the response time of the thermal Pyranometers (less than 60s) and is closer to the solar cell. Its specific performance indicators are shown in Table 2.

Table 2 LI200SB photovoltaic global radiation sensor technical specifications

LI200SB technical specifications	
Spectral range	400~1100nm
Sensitivity (rated)	5μA/1000μmol/sm^2
circumstance	-40~65℃, 0~100%RH
Annual error	<±2%
Standard error	<±5%

3 Test Result and Analysis

3.1 Comparison Under Different Weather Conditions

Solar radiation resources are different in different weather conditions. The observation and evaluation of solar radiation resources under different weather conditions are of great significance for the solar energy utilization. The diurnal irradiance variations of the thermal and photoelectric pyranometer under different weather conditions are shown in Fig. 4, Fig.5, and Fig.6, respectively. As it can be seen from the diagram, the irradiance trends of solar thermal and photoelectric radiation are basically consistent, regardless of sunny, cloudy or rainy weather. The solar thermal irradiance is slightly larger than that of photoelectric, which shows that the solar thermal energy resources are slightly larger than that of photoelectric,

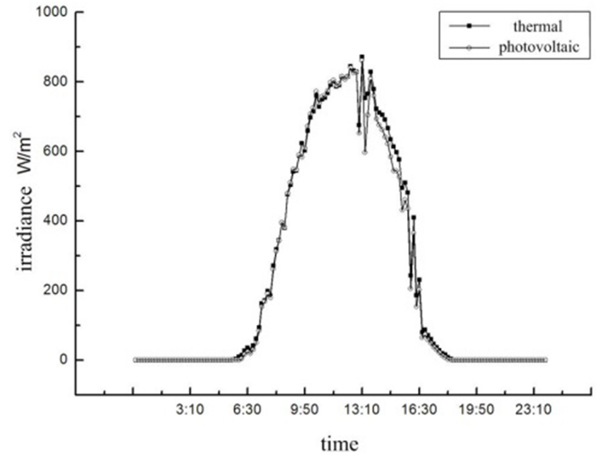

Fig. 4 Daily irradiance changes of solar thermal and photovoltaic sensors in sunny day

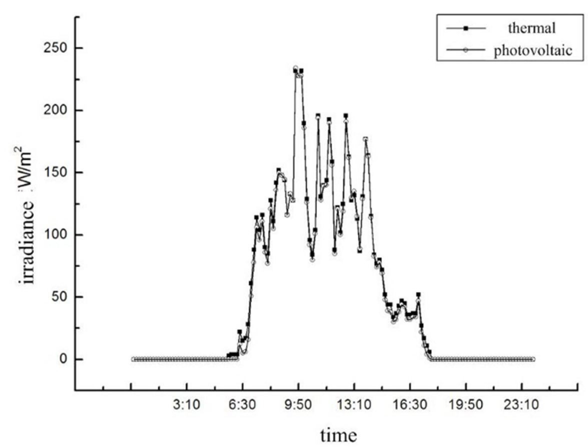

Fig. 5 Daily irradiance changes of solar thermal and photovoltaic sensors in cloudy day

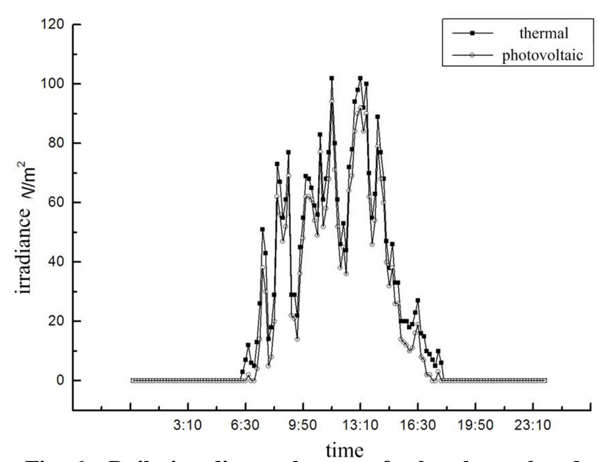

Fig. 6 Daily irradiance changes of solar thermal and photovoltaic sensors in rainy day

The comparison of the diurnalirradiance changes between the thermal and the photoelectric radiometer under different weather conditions are shown in Fig. 7 and Fig.8. As it can be seen from the diagram, under sunny conditions, the maximum irradiance of thermal irradiance is 897w/m^2, which occurs at 13:16pm, and the maximum photoelectric irradiance is 891w/m^2, which occurs at 13:16pm too. Under cloudy weather, the maximum irradiance of thermal irradiance is 243w/m^2, which occurs at 09:56am, and the maximum photoelectric irradiance is 242w/m^2, which occurs at 09:41am.

In the rainy weather, the maximum irradiance of thermal irradiance is 110w/m^2, which occurs at 14:13pm, the maximum photoelectric irradiance is 99 w/m^2, which occurs at 14:13pm too.

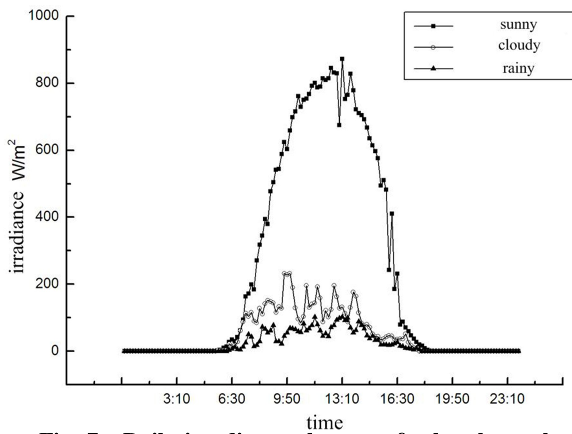

Fig. 7 Daily irradiance changes of solar thermal sensors in different weather conditions

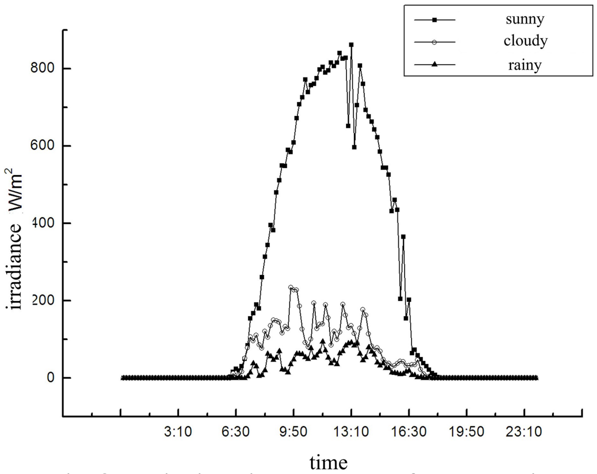

Fig. 8 Daily irradiance changes of photovoltaic sensors in different weather conditions

Asit can be seen from the diagram, the maximum irradiance difference between thermal and photoelectric irradiance is quite different in different weather conditions.

The average daily statistic results show that under sunny condition, the global thermal radiant is about 2.7% higher than photoelectric radiation, under cloudy condition, the global thermal radiant is about 3.9% higher than photoelectric radiation, under rainy condition, the global thermal radiant is about 20% higher than photoelectric radiation.

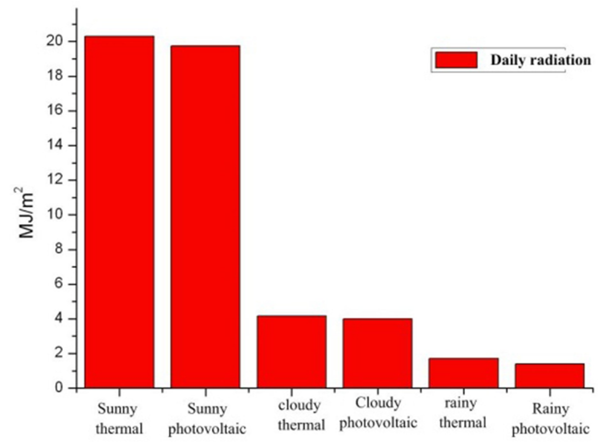

Fig. 9 Daily global radiation changes of solar thermal and photovoltaic sensors in different weather conditions

3.2 Comparison of Solar Energy Resources with Different Tilt Angles

Normally, the solar thermal collector and the solar panels are installed with an inclined angle, so as to achieve maximum solar energy conversion rate, it is very efficient for solar energy utilization.

In this section, the solar energy resources of different tilt angles are analyzed with photoelectric radiometer observation data.

Fig.10 shows the change of the daily irradiance of the horizontally and southerly different tilt angles (obliquity: latitude + 15°, latitude, latitude-15°, vertical elevation).

As can be seen from the diagram, the largest-daily global radiation is latitude-15° and the southern vertical plane is the smallest.

The order from large to small issouth latitude-

15°, south latitude, south latitude+15°, horizontal plane and south vertical surface.

The global radiation of the south latitude-15° is about 41% higher than that of the south vertical surface, as shown in Fig. 11.

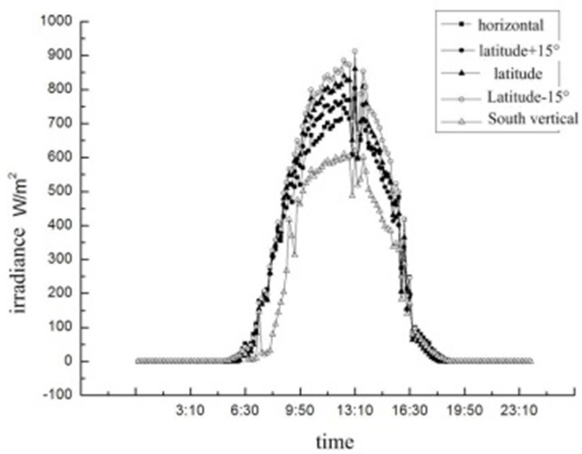

Fig. 10 Daily irradiance changes in different incline

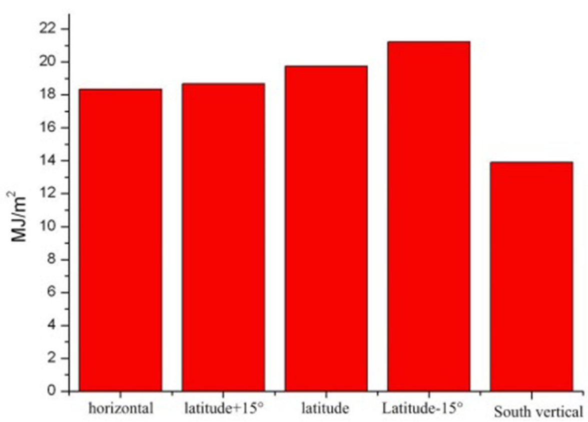

Fig. 11 Daily global radiation changes in different incline

3.3 Comparison of Solar Energy Resources with Different Vertical Surface

Using the buildingvertical surface to install solar utilization equipment is important for the efficient use of solar. In this section, the solar energy resources of different building vertical surface are analyzed with the observation data of photoelectric radiometer.

Fig.12 shows the changes of daily irradiance in the east, south and west vertical surface. As it can be seen from the diagram, the change of irradiance in different vertical surface is closely related to the change of solar time. The irradiance of the East vertical rises rapidly after sunrise in the morning, however, irradiance of the West vertical surface is slow at same time. The irradiance of the East vertical decreases rapidly in the afternoon whereas west side rises rapidly. South surface solar irradiance changes between east and west. South Radiation is the largest, west is the smallest and east is in the middle, as shown in Fig. 13. South radiation is larger than west about 20%, it also has a great relationship with the different seasons.

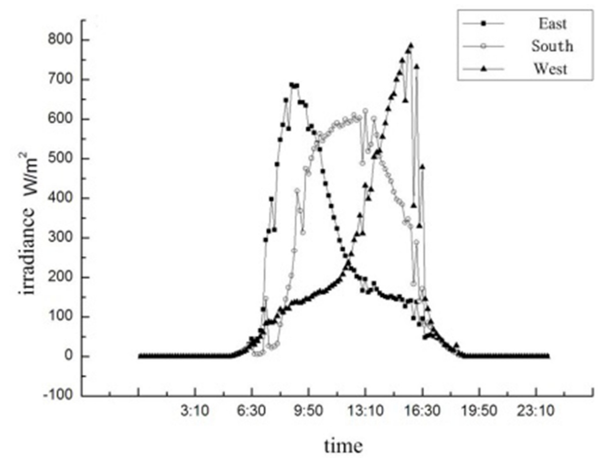

Fig. 12 Daily irradiance changes in different vertical surface

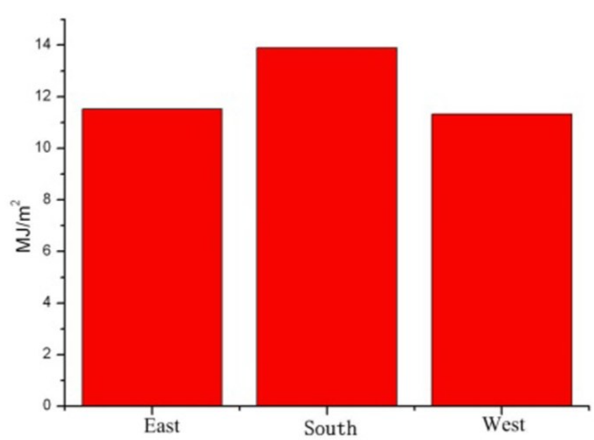

Fig. 13 Daily global radiation changes in different vertical surface

4 Conclusion

Solar thermal and photovoltaic resources observation data in summer were analyzed under different weather conditions, different angles and different vertical surface.

Under sunny condition, the global thermal radiant is about 2.7% higher than photoelectric radiation. Under cloudy condition, the global thermal radiant is about 3.9% higher than photoelectric radiation. Under rainy condition, the global thermal radiant is about 20% higher than photoelectric radiation.

Comparison of solar energy resources with different tilt angles, the order from large to small is south latitude-15°, south latitude, south latitude + 15°, horizontal plane and south vertical surface.

The global radiation of the south latitude-15° is about 41% higher than that of the south vertical surface.

Comparison of solar energy resourceswith different vertical surface, south radiation is the largest, west is the smallest and east is in the middle, as shown in Fig. 14.

South radiation is larger than west about20%, it also has a great relationship with the different seasons.

References

[1] MILLSD. (2004). Advances in solar thermal electricity technology. *Solar Energy*. 76(3), pp.19-31.

[2] Green, M.A. (2000). Photovoltaics: technology overview. *Energy Policy*. 28, pp.989-998.

[3] Ao, XQ. (2008). The molten salt solar thermochemical cycle hydrogen and synthesis gas reaction system. *Journal of solar energy*. 29(12), pp.1528-1533.

[4] Zheng, HF. (2001). Experimental study on an enhanced falling film evaporation-air flow absorption and closed circulation solar still. *Energy*. 29, pp.401-412.

[5] Yin, ZQ. (1998). *All glass evacuated solar energy heat collecting tube*. BeiJing: Science Press.

[6] Zwaan, BZ. (2004). The learning potential of phtovoltaics: implications for energy policy. *Energy Policy*. 32, pp.1545-1554.

[7] Zhang, XL. (2007). Cost benefit analysis and evaluation of social policies for the development of grid connected photovoltaic power generation system in the western region. *Journal of solar energy Energy*. 28 (1), pp.32-36.

[8] Su, H. (2002). Combination model of daily global radiation on a horizontal surface of solar. *Journal of solar energy Energy*. 23(4), pp.514-519.

Authors' Biographies

BIAN Zeqiang, was born in Jiangsu province, China, in 1975. He received PhD from Beihang University, China, in 2008. Now he is an engineer in China Meteorological Observation Centre, China Meteorological Administration, His research interests include solar energy resources observation instruments and observation methods.

E-mail: bianzeqiang@163.com

LYU Wenhua, was born in Hebei province in 1956, he graduated from Tsinghua University in 1979. He is now a researcher at Meteorological Observation Centre, China Meteorological Administration, in Beijing. He is the convener of ISO TC180/SC1/WG2. He has been committed to the value transfer of world radiometric reference in China. his research interests are meteorological instruments design and calibration method.

E-mail: lwhaoc@cma.gov.cn

CHONG Wei, received his BS degree from Anhui Polytechnic University in 2009 and Master degree in signal and information processing from Nanjing University of Information Science and Technology in 2012. He is currently an engineer in CMA Meteorological Observation Centre. His research interests include meteorological measurement, calibration and data processing.

E-mail: chongwei@cma.gov.cn