THE DESIGN OF A 1MW SOLAR THERMAL TOWER PLANT IN BEIJING, CHINA

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ABSTRACT

DAHAN solar plant and the testing platform of China solar thermal power technology would be has been constructed on the lands of the Yanqing District, Beijng, (Longitude 115°44′ to 116°34′、Latitude 40°16′ to 40°47′), 74 km north-west from the city of Beijng. It consists of 10,000m^2 collector field, 100m tower, 8MW thermal power receiver, 1MW steam turbine, and the storage system capacity allows 1 hour full load operation. The main purpose of the tower plant is for the experiment. So more flexible function is asked for the plant system. The purpose of the work is to study the technologies liking system layout design method and performance simulation. The geographer between each heliostat is related to the optical performance and the ratio of shaded ground, considering the plant grow during early of March to end of September yearly. DAHAN includes a 8MW thermal power superheating steam receiver, synthetic oil for high temperature thermal storage and saturated steam for lower temperature storage.

1. INTRODUCTION

Solar power tower technology has been developed since 1970s(J. Gretz, A. Strub,1984,). The 2003 technology baseline is a 13.7-MWe plant using molten salt as the heat transfer fluid, 13 hours of thermal storage, an annual solar-to-electric efficiency of 13.7%, and an LEC of about \$0.15/kWh in solar-resource regions of 2940 kWh/m2-yr(U.S DOE,2003). PS10, to grid in March 2007, is the first commercial solar power tower plant in the world(Rafael Osuna, Rafael Olavarría,2006). The Spain Royal Decree 436/2004 and 661/2007 support the business strongly(Michael Geyer,2007). The DAHAN solar power tower is funded by the Chinese Ministry of Sciences and Technology, Chinese Academy of Sciences and Beijing Municipal Science & Technology Commission. The base task is to found a tower plant, which the net output electricity power is 1MW. The several institutes, university and companies leaded by Institute of Electrical Engineering of Chinese Academy of Sciences are working together on the design, construction and operation of solar tower power plant for the electricity production of 1MW gross power. The identified system is mainly composed of four sub-systems: collector system, receiver system, thermal storage system, power and auxiliary system. The purpose of DAHAN solar tower plant is a testing platform for advance solar concentrator technology, various receiver, high temperature thermal energy transportation and storage and the solar-electricity system operating.

The noon on Spring Equinox(March 21st) is defined as plant design point. The DAHAN tower is the overall height of 100m, and the thermal storage capacity for1hour full load of steam turbine. The testing plant based on the water/steam Rankine cycle will be installed in Yanqing, Beijing, China before December 2010, where about 1600kWh/m^2 the direct normal incident yearly.

The solar collector system concentrates the low-density solar energy into high-density energy, which contains heliostats and tower. The receiver mounted on top of the tower converts the redirected solar beam to thermal energy. The thermal storage system (TSS) is used to store the heat energy. In the system design, the TSS is comprised of a high-temperature storage part and a low-temperature storage part. The heat stored in the low-temperature storage is used to produce saturated steam while the heat stored in the high-temperature storage to produce superheating steam.

2. DESCRIPTION OF GENERIC STSTEM

In DAHAN, owing to the chemical-stability limits of synthetic oil , the maximum working temperature of the high-temperature storage device is limited under 350℃ which lower than the inlet temperature required by turbine-generator; So that, an auxiliary heating system is needed for the electricity power generation (heater fueled by oil or natural gas). The power generation system converts the thermal energy from collector or storage system into mechanical energy and then output. The Fig.1 illustrates the schematic system flow. The heliostats reflect and focus sunlight onto the receiver that is on the top of the tower, the parameters of output superheating steam are 2.5MPa, 400℃, and 8.4t/h steam flux are produced. The high pressure superheated steam from receiver flows along two different pipes: one stream goes into the high-temperature heat exchanger in the high-temperature storage(a) where the synthetic oil is heated to 350℃ and stored as the sensible heat. Then the temperature-decreased steam flows into the low-temperature storage(b) where the mid-temperature heat energy is stored. The low-temperature storage device is a steam heat accumulator. The other way of the superheating steam enters directly into turbine through a pressure relief valve to generate power. The vapor leaving the turbine passes through a condenser, where it condenses on the outside of tubes carrying cooling water. The liquid water then flows into deaerator where it is heated to saturation state by steam from steam turbine after being pressurized up to atmospheric pressure via pump, and finally it is cycled up to the solar receiver again after being compressed to 2.75MPa by water-feeding pump.

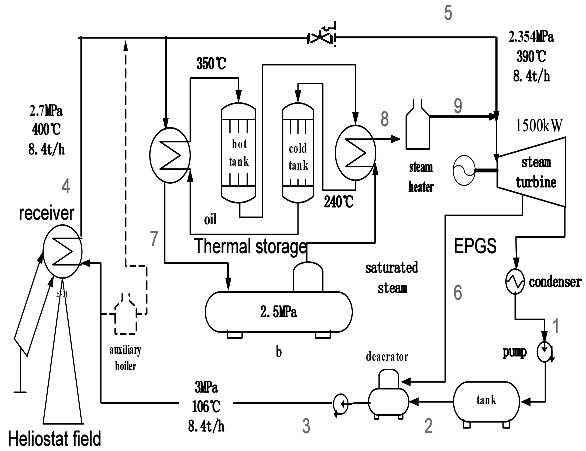

Fig. 1: The energy system(Hongguang Jin, 2007).

For the collector system, the 10,000m^2 heliostats are installed in north of the 100m height tower. The distance og the first row to the tower is about 80m. The reflectivity of the heliostat clean mirror is about 90%, the yearly reflectivity is about 75%.

The thermal storage material uses the synthetic oil and steam firstly in the two stage tanks. A further materials including concrete and molten salt are also studied, which would be used for the plant depending the research situation.

The objectives of the work are to build a testing solar thermal platform. It would be available for the different testing, as liking the heliostat optical performance, water/steam receiver, molten salt receiver, air receiver, the high temperature transportation loop, the thermal storage methods and the high efficiency thermodynamic power cycle. The design and operator method of the solar tower plant are also important.

3. PLANT DEFINITION

Site: Longitude 115°44′ to 116°34′、Latitude 40°16′ to 40°47′.

Design Point: The noon on Spring Equinox, March 21st.

The annual performance is liking Table 1.

$$\begin{aligned}&\text{Net Annual Electricity}\\ &= \text{Net Annual Efficiency} \times \text{Annual DNI} \times \text{Heliostat Area}\\ &= 0.081 \times 1600 \times 10^4\, kWh = 1296\ MWhrs\end{aligned}$$

$$\text{Capacity Factor} = \frac{\text{Net Annual Electricity}}{\text{Plant Power} \times 8760\ \text{hrs}} = \frac{1296}{1 \times 8760} = 14.8\%\ ;$$

Such a lower capacity factor is impossible for the commercial sense. It is just used for the investigating and testing system.

TABLE 1: ANNUAL PERFORMANCE PARAMETERS OF DAHAN

Capacity, MW	1.0
Mirror reflectivity yearly	0.75
Field efficiency yearly	0.74
Mirror cleanliness yearly	0.75
Receiver efficiency	0.90
Storage	0.99
EPGS	0.23
Intercept factor	0.95
DNI, kWh/m2/yr	1600
Annual Efficiency，%	8.1

4. COLLECTOR SYSTEM

The collector mirror area is about 10,000m^2, There are several codes to analysis the heliostat field, for example RCELL, SENSOL, DELSOL, ASPOC and HFLCAL etc..

The maxium F is the purpose of the system designing.

$$F = \frac{yearly \quad collected \quad energy}{System \quad Cost} = \frac{\sum_{i=1}^{8760} A\eta_i I_i}{C_{heliostat} + C_{land} + C_{install}} \qquad (1)$$

The system cost is the sum of the capital cost of heliostat, local ground price and installing infrastructure cost. For the 100m height tower which is available for the 10MW plant for and the 100m^2 aperture heliostat , the result of MAX(F) is as Fig.2(Zhengwu Lu, 2007). The Fig.3 shows the target image from the collector field Fig.2. at 15o'clock in the 23 June., and the most of the reflected radiation is in the 4m×4m target(Zhengwu Lu, 2007). The Figure 4 shows the mean wind pressure C_{pmean} when stacking front facade with back façade from the wind tunnel experiment(Zhifeng Wang 2007). Fig.5 is the heliostat.

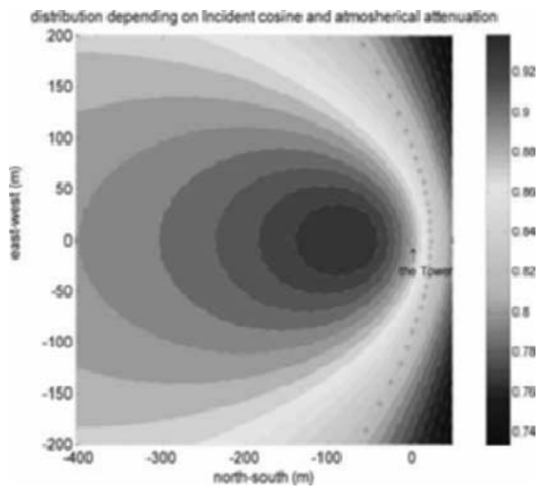

Fig. 2: The layout of collector field.

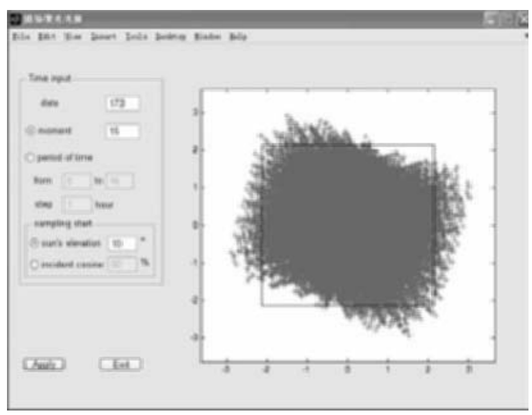

Fig. 3: The target image of collector field.

5. RECEIVER SYSTEM

The receiver supports the superheat steam for the turbine. The two phase heat transfer will be inside the absorber. tubes. Thus the more difficult technologies are linked to keep the high safety performance. The process are related with preheating, saturated evaporating, boiling tank and superheating.

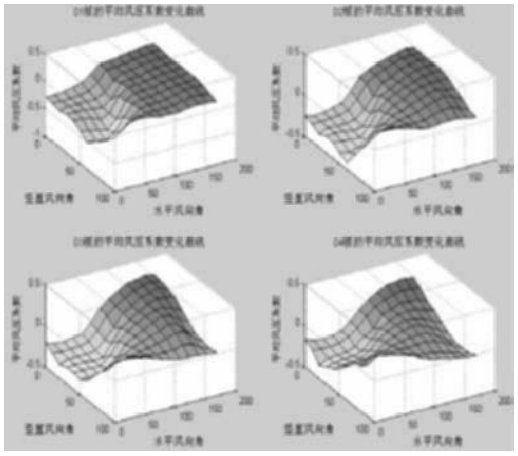

Fig. 4: Variation curve of C_{Pmean} on plate.

Fig. 5: DAHAN heliostat.

6. CONCLUSIONS

The DAHAN STP uses the water/steam Rankine cycle. The 6 types of heliostat have been developed for the project. The receiver would support 400°C, 2.5MPa superheating steam for the turbine. The both of the direct and indirect couple cycles have been arranged for the system. Thus the system is available for the solar-only or hybrid running with oil/nature gas. It is useful for the testing loop system.

7. REFERENCES

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