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중국 1 MWe급 태양열발전시스템에 대한 기초 운전해석

Zhihao Yao[1], Zhifeng Wang[2], 강 용혁[3], 김 종규[4], Xiudong Wei[5]

Preliminary Simulation Study on 1 MWe STP System in China

Zhihao Yao, Zhifeng Wang, Yongheack Kang, Jongkyu Kim, Xiudong Wei

Key words : Heliostat Field(반사판), Receiver(흡수기), Rankine Cycle(랭킨사이클), DNI(Direct Normal Irradiation, 직달일사량)

Abstract : DAHAN, the first 1 MWe Solar Power Tower system locates north to Beijing where nearby The Great Wall is now under construction with cooperation between China and Korea. Results in predicting the preliminary performance of this central receiver system are presented in this paper. Operating cycles under some typical weather condition days are simulated and commented. These results can be used to assess the impact of alternative plant designs or operating strategies on annual energy production, with the final objective being to optimize the design of central receiver power plants. Two subsystems are considered in the system simulation: the solar field and the power block. Mathematic models are used to represent physical phenomena and relationships so that the characteristics of physical processes involving these phenomena can be predicted. Decisions regarding the best position for locating heliostats relative to the receiver and how high to place the receiver above the field constitute a multifaceted problem. Four different kinds of field layout are designed and analyzed by the use of ray tracing and mathematical simulation techniques to determine the overall optical performance η_{field} and the spillage η_{spill} .The power block including a Rankine cycle is analyzed by conventional energy balance methods.

1. Introduction

Although power towers are commercially less mature than parabolic trough systems, a number of component and system experiments have been fielded around the world in the last nearly 30 years. In Table 1, these experiments are listed along with their more important characteristics[1]. A "power tower" solar -thermo-electric plant comprises a field of many mirrors controlled as heliostats which focus sunlight onto a receiver mounted on a tower. The resulting thermal energy is transferred by means of a working fluid, or fluids, to an electricity generator in this

1) 한국에너지기술연구원 (Institute of Electrical Engineering, Chinese Academy of Science)
E-mail : zhyao@mail.iee.ac.cn
Tel : (042)860-3744 Fax : (042)860-3739
2) Institute of Electrical Engineering, Chinese Academy of Science
E-mail : zhifeng@vip.sina.com
Tel : +86-010-62520684 Fax : +86-010-62587946
3) 한국에너지기술연구원
E-mail : yhkang@kier.re.kr
Tel : (042)860-3518 Fax : (042) 860-3739
4) 한국에너지기술연구원
E-mail : rnokim@kier.re.kr
Tel : (042)860-3477 Fax : (042) 860-3739
5) Changchun Institute of Optics, Chinese Academy of Science
E-mail : wei.xiudong@yahoo.com.cn
Tel : +86-010-62520684 Fax : +86-010-62587946

DAHAN project water and a steam driven alternator, respectively. Optionally some means of short term energy storage may be included in this plant high pressure saturated steam and silicate oil to allow the plant to continue operation during, for example, the passage of clouds. DAHAN, the first 1 MWe Solar Power Tower system locates north to Beijing where nearby The Great Wall is now under construction with cooperation between China and Korea. The plant mainly consists of collector system(CS), receiver system(RS), thermal storage system(TTS), electrical power generation system(EPGS) and the balance of plant(BOP). The plant in design's main equipments layout is as shown in Fig. 1.

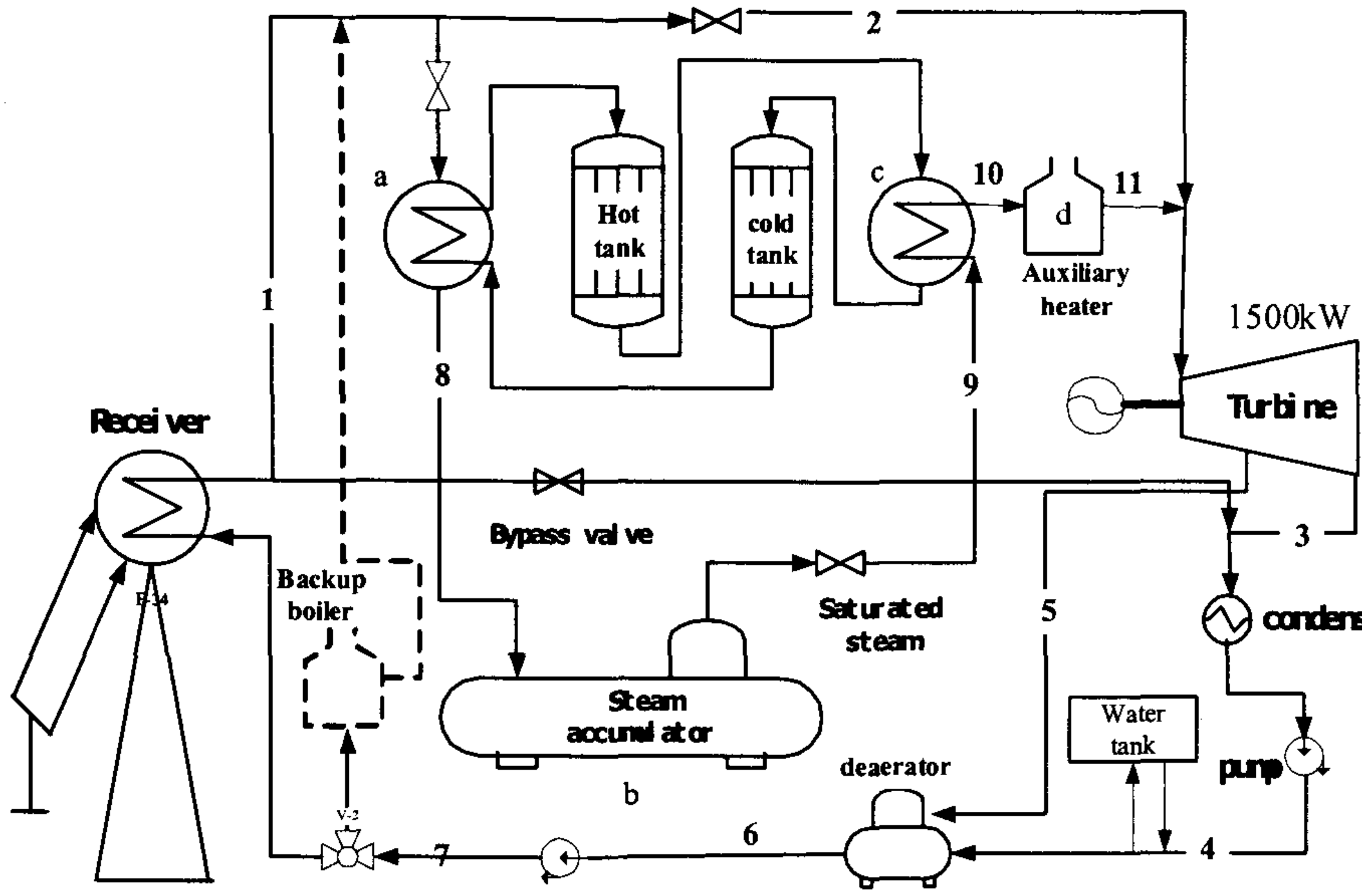

Fig. 1 Conceptual Diagram of the DAHAN SPT Plant

Table 1. List of the SPT project in the world

Project	Sponsor	Power (MWe)	Heat transfer fluid	Storage Medium	Operation began
Eurelios	Italy	1.0	Steam	Nitrate Salt/Water	1980-1984
Sunshine	Japan	1.0	Steam	Nitrate Salt/Water	1981-1984
SSPS-CRS	Spain	0.5	Liquid Sodium	Sodium	1981-1985
Solar-One	USA	10	Steam	Oil/Rock	1982-1988
CESA-1	Spain	1.2	Steam	Nitrate Salt	1983-1984
Themis	France	2.5	Hi-Tec Salt	Hi-Tec Salt	1983-1986
MSEE /Cat B	USA	1.0	Molten Salt	Nitrate Salt	1984-1985
SPP5	Russia	5.0	Steam	Water/Steam	1985-1989
PHOEBUS-TSA	Europe	1.0	Air	Ceramic	1992 -
Solar two	USA	10	Molten Salt	Nitrate Salt	1996-1999
PS10	Spain	11	Steam	Steam	2007.3 -
PS20	Spain	20			2008 -
Solar Spire	Israel	0.25	Air		2000 -

2. Main component models description

2.1 Heliostat field layout

Decisions regarding the best position for locating heliostats relative to the receiver and how high to place the receiver above the field constitute a multifaceted problem, in which the land cost and various heliostat power loss mechanisms are the main variables. These mechanisms include the cosine effect, reflectance loss, shadowing and blocking, atmospheric transmittance and spillage efficiency. For accurate prediction of the thermal performance of a central receiver system, it is necessary to define the flux profile produced on the receiver by a large number of representative heliostats throughout each day of a typical year. This is done by the use of ray tracing and mathematical simulation techniques to determine the overall field efficiency which is expressed as[2)]

$$\eta_{field} = \eta_{\cos}\eta_{shadow}\eta_{block}\eta_{refl}\eta_{atten} \qquad (1)$$

Four different kinds of suggested 'fields specified as North-South cornfield layout, North-South staggered layout, Radial cornfield layout and Radial staggered layout as shown in Fig 2, 3, 4, and 5 were analyzed optically and thermally in this paper.

2.2 Receiver energy loss estimation and thermodynamic model

A cavity receiver composed of boiler panel, superheat panel, steam drum and a door was designed in DAHAN project. Among the most desirable features of the cavity are its near-black-body absorption, the flexibility of designing the interior to attain nearly uniform flux at the heat conversion interface and ease of insulation. Four mechanisms of conduction, emission, convection and reflection effect cause the receiver's energy loss. Before experimental tests and computer models developed, some basic correlations recommended can be used for estimation at "quasi-stationary" state. For example, the basic correlation for natural convection from a cavity receiver can be expressed as [3)]:

$$Nu_L = 0.088 Gr_L^{1/3} \left(T_W / T_a\right)^{0.18} \qquad (2)$$

Nu_L = the Nusselt number, based on the height of the interior of the cavity L

Gr_L = the Grashof number, based on the height of the interior of the cavity L

The receiver thermodynamic model based on energy balance is shown in Fig 6.[4)]

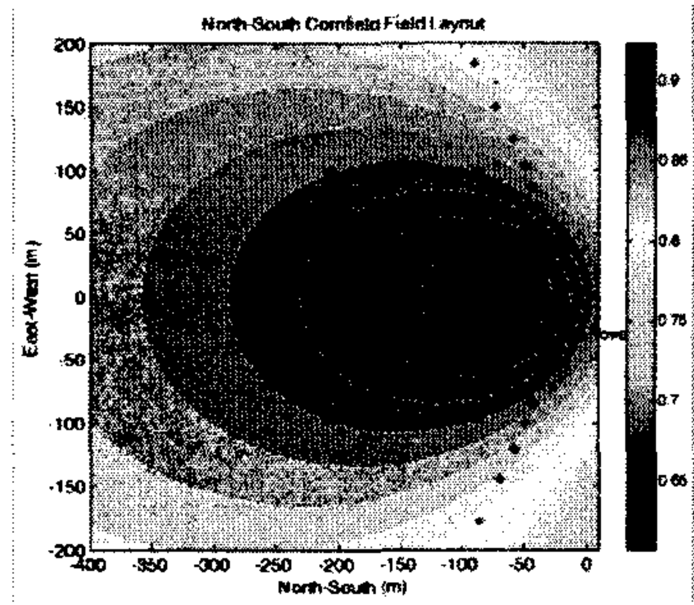

Fig. 2 North-South cornfield layout

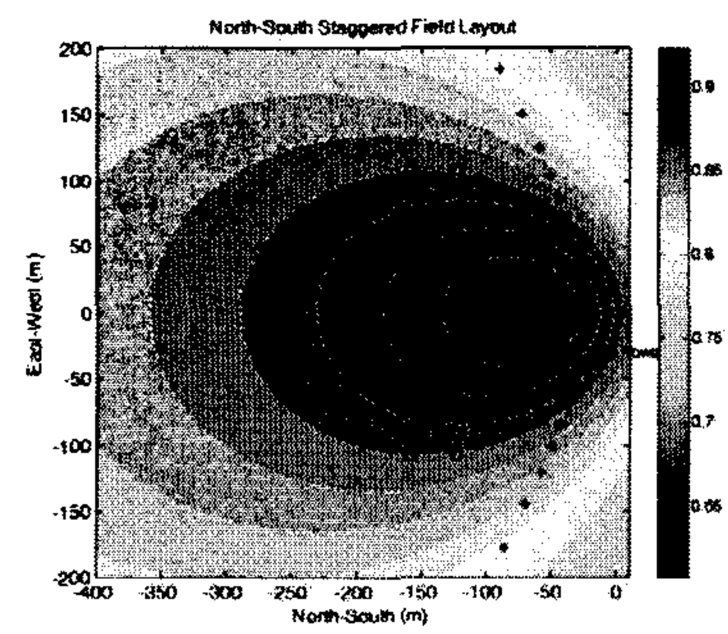

Fig. 3 North-South staggered layout

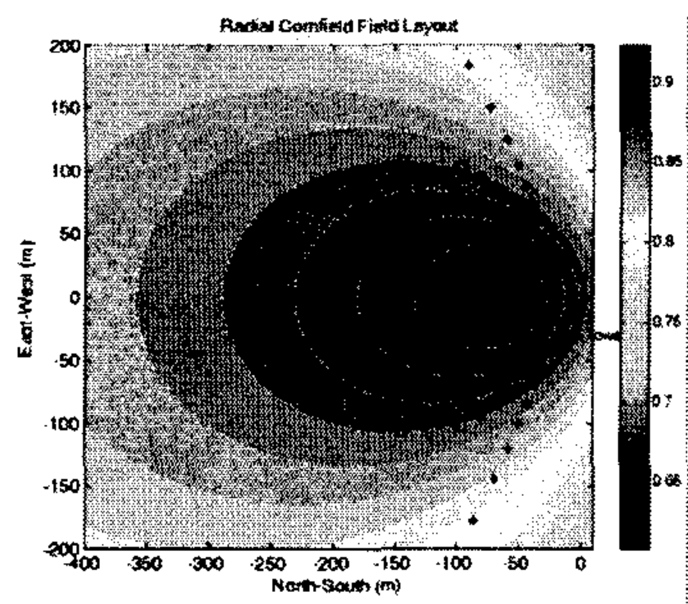

Fig. 4 Radial cornfield layout

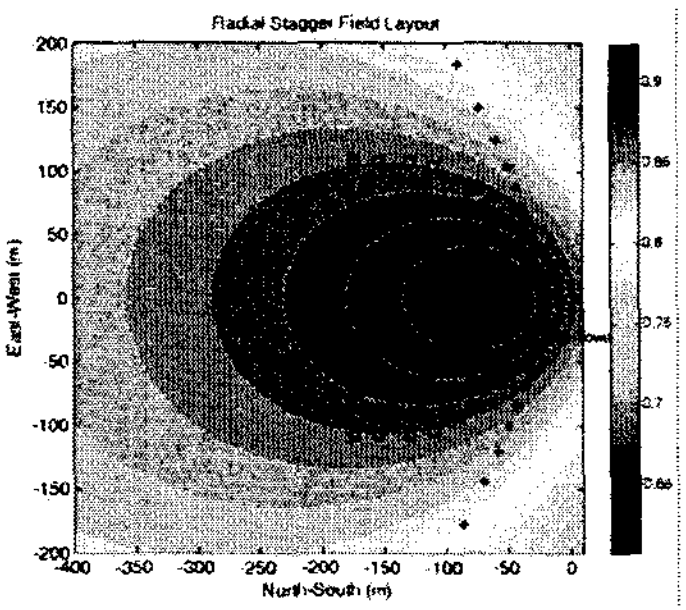

Fig. 5 Radial staggered layout

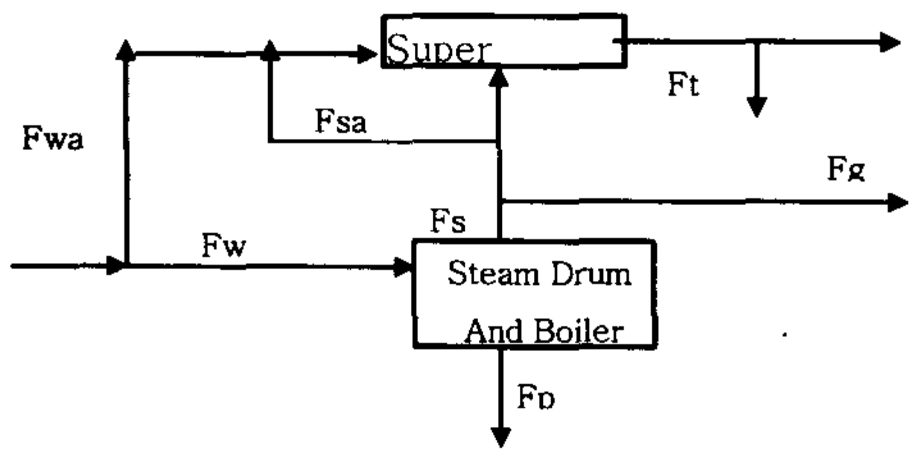

Fig. 6 Receiver thermodynamic model

Where, Fwa= attemperation water flow, Fp= blow down flow, Ft= steam flow to the turbine/storage, Fg= turbine gland steam flow, Fs= saturated steam flow, Fsa= spraying steam flow, Fw= feed water flow.

2.3 Rankine Cycle

The Rankine cycle in the system simulation model mainly consists of high and low pressure turbine stages with controller and bypass loop, feed water heaters, deaerator and condenser. If the turbine in operation is coupled with thermal storage system, then evaporator and super heater are also included.

3. Simulation

After comparison of the four kinds of heliostat field layout, the North-South staggered type is preferred for its low cost and high annual efficiency. Taking into consideration for the annual performance estimation reference, the rating point was chosen at 12:00 on Mar 22nd which is Spring Equinox with DNI 830 W/m^2. The daily electricity generation power adjusted to the changing DNI value is as shown in Fig 7. From this simulation results, it can be found that 7 hours' generation power more than 1 MWe available under such typical daily weather.

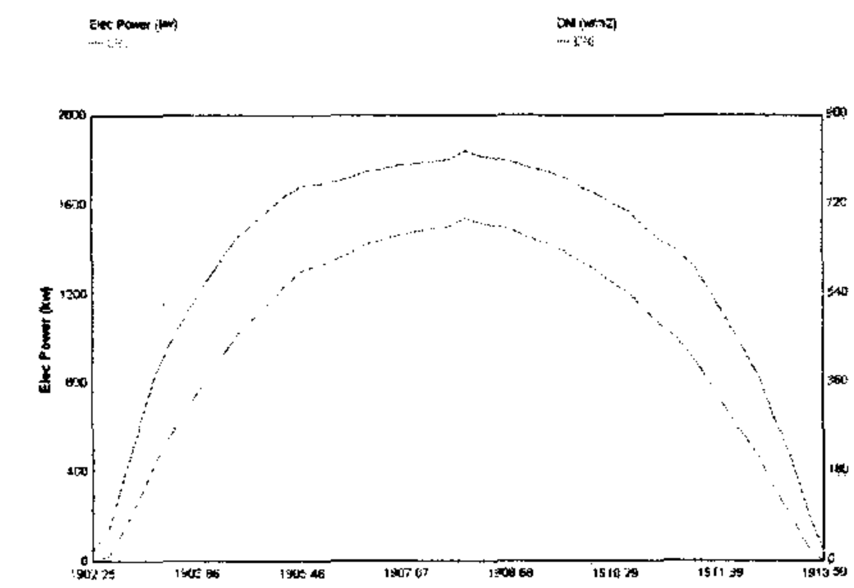

Fig. 7 Daily electricity generation power adjusted to the DNI value

4. Conclusions

The simulations made above show that DAHAN plant can successfully generate the expected electricity on annual basis. For more transient performance analysis, complicated components models are needed. To such a plant under construction, it's not easy to find the proper models in detail so it remains the target in the coming research.

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