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# Production of electricity and desalinated water by a central solar tower in Thermoflow software

**Poorhamidi, A.R1*., Khoshhal, H2., Ghezelbash, P.3**

[1]National standard organization of Iran. Alireza.poorhamidi@yahoo.com

[2]National standard organization of Iran; Ha_Khoshhal@yahoo.com

[3]Energy consumption criteria standard implementation; P_ghezelbash@yahoo.com

**ABSTRACT:** In this paper, applying a solar tower for generating super heated steam at 540 C and using it to drive a steam turbines is investigated in Thermoflow software. The steam goes through the power block to generate electricity. By using a solar tower instead of traditional boiler, it is possible to generate 524040 kW power. An extraction of steam turbine is used as the heating steam in MED plant to generate 30 t/h desalinated water. First, we will present some important characteristics of solar tower and then we will simulate solar tower, power block and also desalination plant by Thermoflow software to inspect technical aspects of each part by details.

**KEYWORDS:** Solar Tower, Power Generation, Heat Transfer, Receiver, Efficiency, Brine Water, Desalination, Thermoflow.

## INTRODUCTION

The use of fossil fuels has produced large amounts of air pollution due to the release of harmful gases as combustion byproducts. Industries have been turning towards new, clean solutions to their energy needs. Solar thermal power plants are the only option able to produce electricity from sustainable sources with the least influence on the environment [1]. Among all solar thermal technologies, central receiver systems (CRS) have the highest potential for cost reduction of electricity produced [2]. A solar receiver power plant involves the use of a field of mirrors called heliostats pointed towards a receiver atop a large tower. The field of heliostats acts as a large parabolic reflector broken into small segments. The receiver heats up due to the incoming solar radiation flux and transmits heat to a heat transfer fluid. This fluid is usually water, air or molten salt. The heat transfer fluid is then used to run a turbine that produces electricity through generator [3]. Several studies have been conducted in this area that we will mention to some of them here. It is the goal of Plant Solar 10 (PS10) project to design, construct and operate a 10 mw plant to the existence of a desalination plant which is able to distillate brine water and make fresh water. By this method, we can also generate 30 t/h desalinated water.

## MATERIALS AND METHODS

## SOLAR GEOMETRY

be installed in southern Spain and producing electricity in a grid connected mode [4]. Haaf gives test results and a theoretical description of the solar tower prototype in Manzanares, Spain [5]. Kreetz introduces the concept of water filled bags under the collector roof for thermal storage. Gannon presents a thermodynamic cycle analysis of the solar tower. Ruprecht gives results from fluid dynamic calculations and turbine design for a 200 mw solar tower [6]. A thermal and technical analyses targeting computer aided calculation is described Santos Bernardes. In Australia, a 200 MW solar tower project is also being developed [7]. J. Ignacio investigated on a central receiver system using molten salt as heat transfer fluid and found the receiver efficiency at %88 and its gross Rankine cycle efficiency at %34 [8]. L.j Yebra presented a model that will be used in design of hybrid model predictive control and intelligent control schemes to optimize plant performance under start-up and shut-down situations [9]. In this study, we are going to assess a solar tower which is able to provide steam at 540c. This Solar tower is also coupled with a Rankine cycle to generate electricity. The essential character of this study is In order to predict the location of the sun for heliostat tracking, the geometry is defined as follows in Table 1 [10].

## RESULTS AND DISCUSSION

As shown in Figure 1, a solar tower is used to generate steam. This steam enters the turbine and hence produces electricity. An extraction of turbine is also used as the heating steam in MED plant which results in fresh water.

Direct normal irradiance of solar plant is 841.1 W/m$^2$ and total heat transfer to network is 1521080 kW. Heat transfer to fluid in receiver is 380329 kW. The flow diagram of solar tower is represented in Figure 2. As shown in Figure 2, the outlet steam of solar tower is at 540c and 1632.9 t/h. As shown in Figure 3, the peak direct normal irradiance of receiver is 841.1 W/m$^2$. The tower height is 200 m, tower inner diameter is 15.63 m. Reflective area per field is 1228154 m$^2$ and 27540 heliostats exist in the tower. Earth declination angle and solar zenith angle are at 23.45 degree, solar altitude angle is also obtained 66.55 degree. There are also 4 tower fields in in this project.

**Table 1.** Solar plant Geometery definitions

| | |
|---|---|
| $\omega$ | Hour angle |
| $\theta i$ | Angle of incidence |
| $\theta z$ | Zenith angle |
| $\propto$ | Solar altitude angle |
| $\varphi$ | Latitude |
| $\delta$ | Declination |
| $\beta$ | Tilt |
| $\gamma$ | Heliostat azimuth angle |

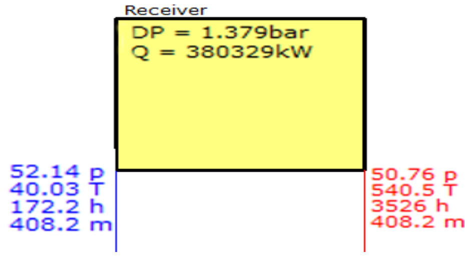



**Fig. 2.** Solar tower receiver, p[bar], T[C], h[kJ/kg] m[t/h]

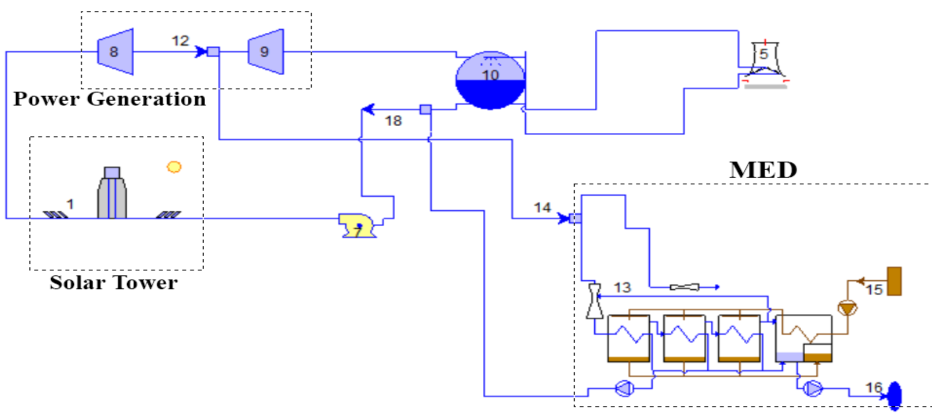



**Fig. 1.** Plant simulation

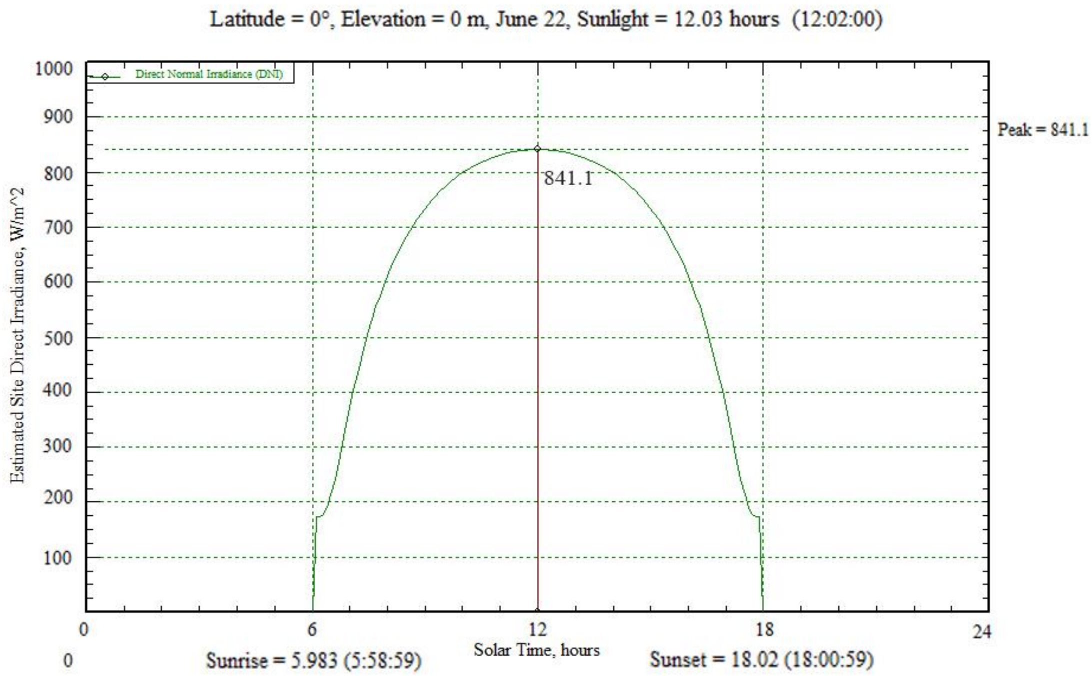


**Fig. 3.** Direct irradiance versus time

Cold pipe inlet, receiver inlet, receiver exit and hot pipe outlet characteristics per each tower field are shown in Table 2.

**Table 2.** Flow characteristics through solar tower

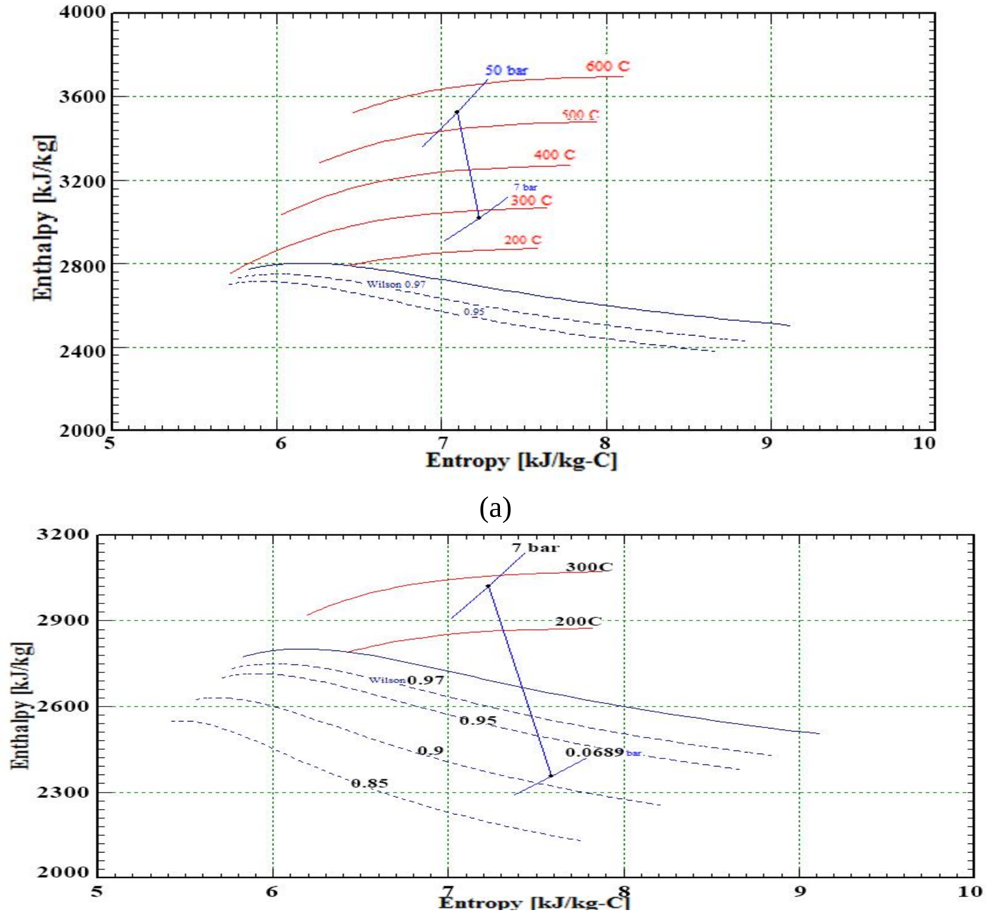
| Characteristic | Cold pipe inlet | Receiver inlet | Receiver exit | Hot pipe outlet |
|---|---|---|---|---|
| Pressure | 72.7 bar | 52.14 bar | 50.76 bar | 50 bar |
| Temperature | 39.64 C | 40.03 C | 540.5 C | 540 C |
| Enthalpy | 172.3 kJ/kg | 172.2 kJ/kg | 3526 kJ/kg | 3526 kJ/kg |
| Mass flow | 408.2 t/h | 408.2 t/h | 408.2 t/h | 408.2 t/h |
| Heat loss | 39.57 kW | - | - | 19.78 kW |

Other important parameters of power plant are indicated in Table 3.

**Table 3.** Power block results

| Parameter | Unit | LHV | HHV |
|---|---|---|---|
| Net heat rate | [kJ/kWh] | 10685 | 10685 |
| Net electric efficiency | [%] | 33.69 | 33.69 |
| Net power | [kW] | 524040 | |
| Total auxiliaries | [kW] | 11554 | |

At the first steam turbine, expansion power is 229628 kW, inlet pressure is 50 bar and dry step efficiency equals to 85 percent. Inlet control type is also sliding. At the second steam turbine, expansion power is 300509 kW, inlet pressure is 7 bar, exit pressure is 0.0689 bar which leads to the spray condenser with 0.9 of quality. Steam turbine expansion paths are also shown in Figure 4 a and b for the first and second turbines, respectively.




(a)

(b)

**Fig. 4.** Expansion path of first steam turbine (a) and (b) second turbine

An extraction of first turbine outlet is taken to be used as the heating steam of MED plant at 7 bar and 280.9 C. Its mass flow is also 5.749 t/h. MED plant is shown in Figure 5.

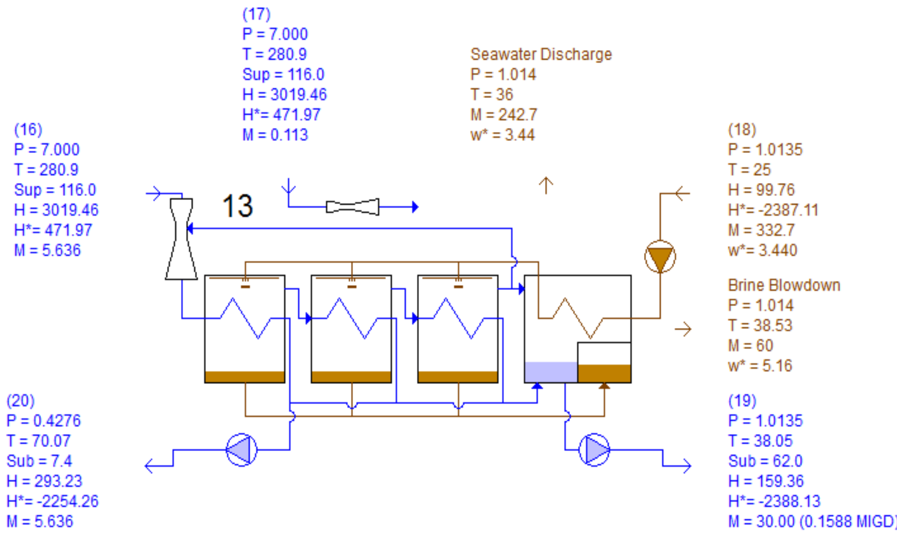
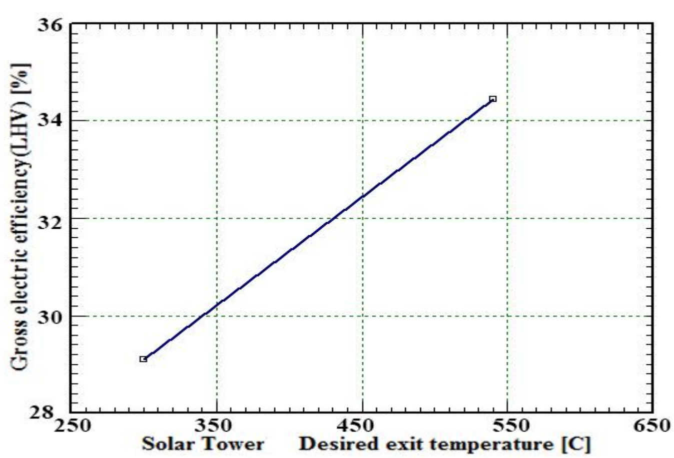



**Fig. 5.** MED plant, P[bar], T[C], H[kJ/kg], M[t/h]

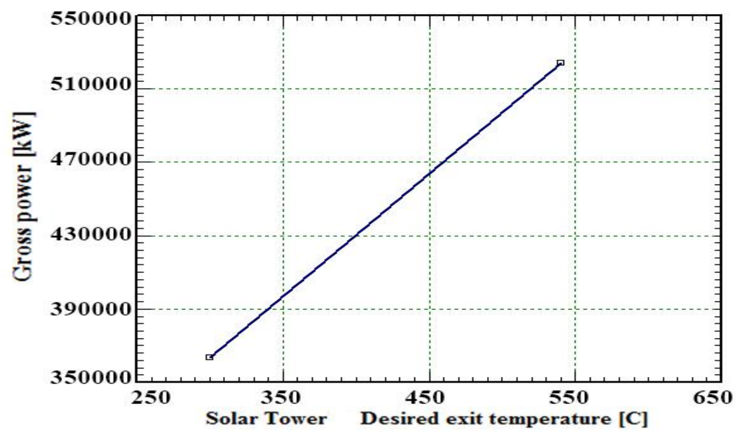
As shown in Figure 5, the plant is able to receive 332.7 t/h brine water and deliver 30 t/h desalinated water. The heating steam extracted from turbine enters the plant at 280.9 C and then returns to the condenser hot well at 70.07 C. performance ratio of MED is 4.541 and involves 5 effects. Total electrical consumption of MED is 49.47 kW.
There important parameters of system are also investigated versus receiver outlet temperature. As can be seen in Figure 6 a and b, gross power and gross electric efficiency, increase rapidly versus receiver outlet temperature rise.

## CONCLUSION

In this paper, we emphasized on the importance of renewable energies such as solar towers which can generate required steam of steam turbines. On the other hand, we applied another kind of renewable energy source like desalination plant to generate fresh water at the same plant. By using solar tower instead of fossil fuel boiler, we can generate 524040 kW electricity with the efficiency of 33.69 percent. Total desalinated water produced by MED system is 30 t/h. This project is absolutely useful in sunny areas where also face lack of water.




(a)




(b)

**Fig. 6.** Gross electric efficiency and gross power

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