Contribution to the study of a solar tower concentration in Algeria

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***Abstract-** The concentrating solar power plants such as solar are excellent alternatives to conventional especially in countries which lie in the Sun Belt. These solar power plants, there are power towers that have shown their ability.*

In this work, we propose the design and simulation of a solar tower power to produce 15 [MWe] of utility-scale electric power each from solar thermal energy input, for its implementation in Algeria. It is usually divided into two subsystems: the solar field and power cycle (Rankine cycle).

A numerical model of the solar field and power cycle were determined using the library STEC of the software TRNSYS. The site selected for the simulation is Tamanrasset located in south of algeria , weather data is include in TRNSYS from his collection (tm2).

The steady-state power cycle performance was regressed in terms of the heat transfer fluid temperature, heat transfer fluid mass flow rate, and condensing pressure, and implemented in TRNSYS.

Keywords: Solar tower power, TRNSYS, Simulation, Solar Energy, STEC

I. INTRODUCTION

The solar potential of Algeria [1] is among the largest in the world. More than 2 million km2 of the country receive sunshine of around2500 KWh/m2/year. The exploitation of this potential solar allows us to complete the rural electrification programs. The electrification rat in our country today is 95% use of renewable energy allows us to reach, in particular, remote and very remote from the national grid.

"Solar thermal" all the techniques that aim to transform the energy radiated by the sun into heat at high temperature [2], then it into mechanical energy (and power) through a thermodynamic cycle. Concentrating solar technologies allow transforming solar radiation into heat at a temperature between 200 °C and 2000 °C, with a yield above 70%.

This primary heat can then be used in processing, or synthetic materials or be converted into energy carrier like electricity or hydrogen. These techniques are still, essentially, in an experimental state.

The solar tower [3] consists of many mirrors focus sunlight to a receiver in atop of tower. The advantage of the solar tower compared to parabolic trough is that losses to the ambient are lower because the exposed surface is limited.The mirrors are called heliostats evenly distributed. Each heliostat tracks the sun and reflected individually in the direction of a receiver at the top of the solar tower. The concentration factor ranges from 600 to several thousand, which allows reaching high temperatures, of 800 ° C to 1000 ° C

Although power towers are commercially less mature than parabolic trough systems, a number of component and experimental systems have been field tested around the world in the last 15 years, demonstrating the engineering feasibility and economic potential of the technology. Since the early 1980s, power towers have been fielded in Russia,Italy, Spain, Japan, France, and the United States [2]. these experiments are listed along with some of their more important characteristics. These experimental facilities were built to prove that solar power towers can produce electricity and to prove and improve on the individual system components.

Our work is to study and simulate the performance of solar power towers with 15 MW for the site of Tamanrasset, a central with air receiver .For this we used the simulation software TRNSYS and the STEC library components (Solar Thermal Electric Component)

II. PRINCIPLE OF CONCENTRATION

To convert sunlight into heat, just in principle to receive it on an absorber. But even if such a receiver is perfectly absorbent losses are very meant to happen. These losses are a first approximation proportional to its own heating and the developed area. [4]

To work at high temperature, which is necessary here to feed an efficient thermodynamic cycle, we must greatly reduce the receiving surface to maintain, in proportion, these losses to a reasonable level. This is what is done by placing the receiver in front of "heliostats" mirrors which concentrate on it the collected radiation over an area much greater. We characterize the system performance by the value of its "concentration" which is the ratio of the surface collection on the receiver surface. Figure 1 illustrates the principle of concentration.

Any installation of solar tower power plants must perform the same functions to transform the energy of the incident radiation into electrical energy as efficiently as possible. They are discussed below in the following order:

- The concentration of radiation to the receiver input,
- Its absorption by the walls of the receiver and the transformation of its energy into heat,
- Transport and possible storage of the heat,
- Transfer of this heat to a thermodynamic cycle associated with an alternator for generating electricity.

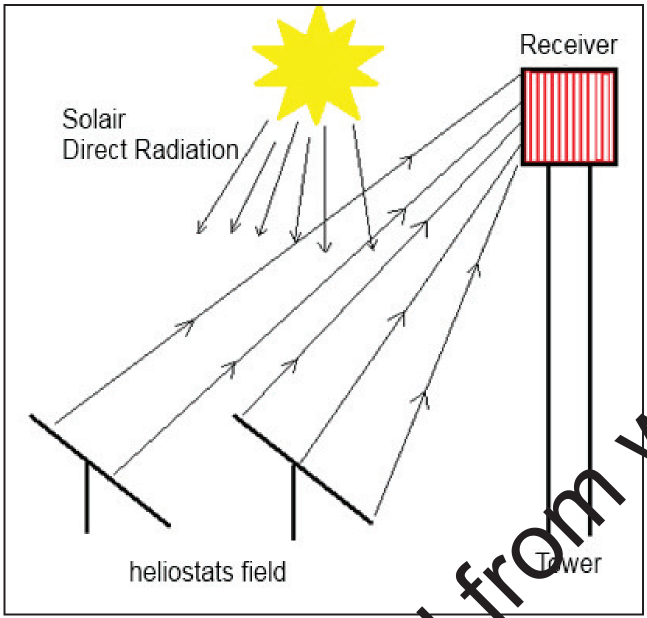

Figure 1. Principle of concentration

The receiver is the component that will convert the sunlight into heat supplied to the transfer medium. It is exposed to harsh environmental conditions (temperature, dust, rain, humidity...).

Fig. 1 depicts the schematic of a solar power tower plant using water vapor as the heat transfer fluid. Since this paper the thermal storage subsystem will not be discussed and not shown in (Fig. 1) without considering the thermal storage subsystem.

III. PERFORMANCE SIMULATION OF THE COMPLETE INSTALLATION

A. TRNSYS MODEL

The system of our tower power was modeled using the STEC TRNSYS library [5].The simulation is performed on one day, with a production constraint at full load of 6 hours to 20 hours.

The weather data are from the internal library of TRNSYS for May 1 on the area of Tamanrasset located in south of Algeria[6] .

The variation of the direct irradiation is shown in (fig.2). The average radiation directly on the site of Tamanrasset is the order of3643 kj/hr.m² à from the reasons for and importance of isolation, our choice of the site focused on Tamanrasset.

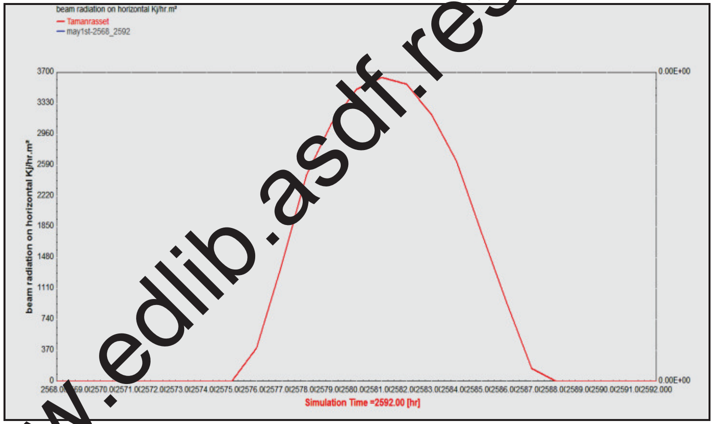

Figure 2. Direct normal irradiation (DNI) for may 1st in the area of Tamanrasset

The heliostat field is represented by her matrix of efficiency calculated by SOLTRACE and include in the library of TRNSYS.

The receiver model takes into account reflection losses and infrared receiver, the opening of the receiving cavity is represented by a gray body diffusing emissivity e (Table 1)

TABLE I .Technical Data of solar power tower 15 Mw

Subsystem	Properties	Values	Unit
Heliostat field	Mirror surface area	90	m²
	N° of concentrator units	1000	-
	Reflectivity	0.85	-
Central receiver	Aperture area Inlet cold air temperature Outlet hot air temperature absorber fraction surface area of piping	170 370 665 1 1 0.9 0.95	m² °C °C - m² - -

	emissivity optical efficiency ambient temperature	30	°C
Steam generator subsystem	Inlet temperature of water Outlet temperature of steam Condenser output temperature Condenser output pressure	200 320 50 0.5	°C °C °C bar

(Fig.3) shows the graphical user interface of TRNSYS. The modules for the components and input instructions are interconnected with arrows corresponding to their input-output

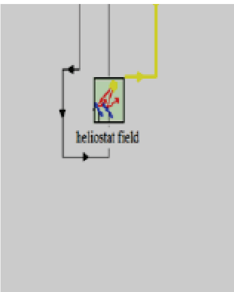

Figure 3. Graphical interface of TRNSYS (the modules corresponding to the outputs (plotter, printer) are not represented)

B. *Description of Work and Main Results*

Our works is solar concentration solar thermal (CST) tower plant working with direct saturated steam generation (DSG) concept, at considerably low values of temperature and pressure (320ºC & 80bar) (fig.4).

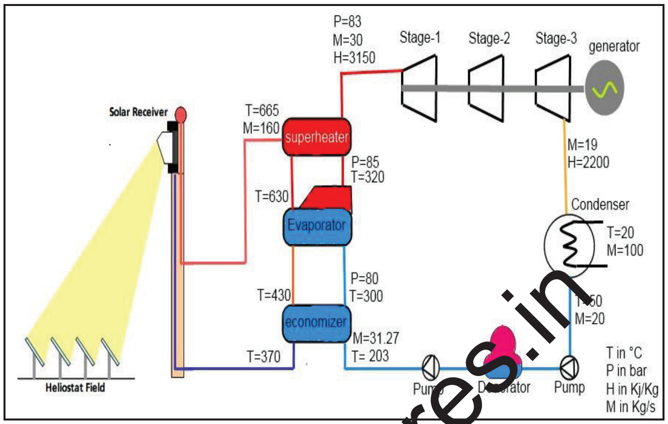

Figure 3. Schematic drawing of a solar tower plant with Results from TRNSYS

The heliostat field is composed by 1000 heliostats for a total reflective surface of 90 000m². Each heliostat is a mobile 90 m² curved reflective surface mirror that concentrates solar radiation on a receiver placed on top of a 80 m tower. For this purpose, every heliostat is spherically curved so its focal point is at a distance equal to the slant range to the receiver.

Tower frontal view requires of about 18m allocating 13m width receiver. A big open area has been proposed in the center of the body to achieve a lighter structure perception. (Table1)

At the top of the tower is placed the receiver. The receiver is the system where concentrated solar radiation energy is transferred to the working fluid to increase enthalpy is based on cavity concept to reduce as much as possible radiation and convection losses. The receiver is basically a forced circulation radiant boiler with low ratio of steam at the panels output, It has been designed to produce above 160 kg/s of saturated steamat 80bar- 650ºC from thermal energy supplied by concentrated solar radiation flux.

It is formed by tubes to conform an overall heat exchange surface (Aperture area) of about 170m². These panels are arranged into a semi-cylinder of 1m of radius.

During operation at full load, absorber panels will receive about 66.5MWt (2,392.10^{8}kj/h) of concentrated solar radiation showingin the graph(fig.5).

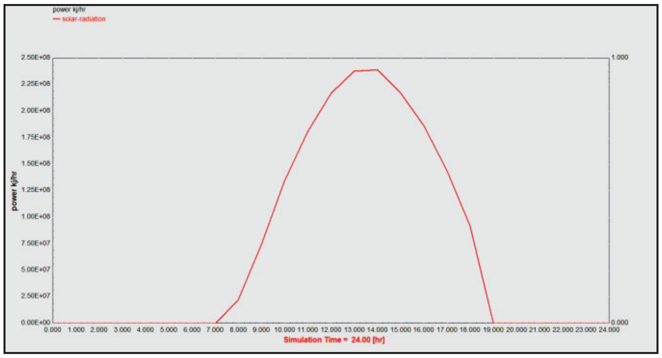

Figure 5.Concentrated solar radiation reflected by the heliostat filed

Steam produced in the receiver is sent to the turbine where it expands to produce mechanical work and electricity. the turbine operates at 320ºC and 83bar saturated steam conditions is illustrating in the graph (fig.6)

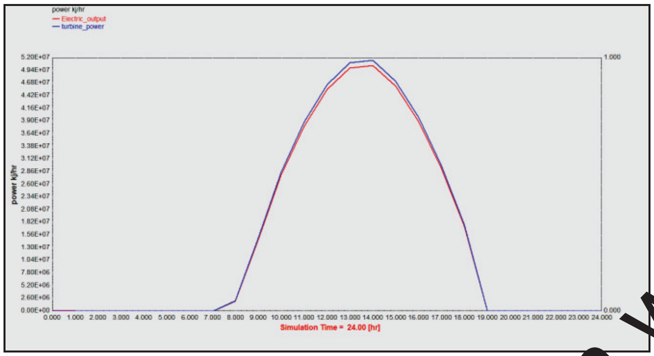

Figure 6. Electric power and generated power of the turbine

At the exit is sent to a low pressure water-cooled condenser. Condenser exit is preheated with turbine extractions at low and medium pressures. Output of first preheater is sent to a deaerator, fed with steam from another turbine extraction. A third and last preheater is fed with steam from receiver. It increases water temperature till 203ºC. When mixed with returned water from drum, a 370ºC undercooled input feed to the receiver is obtained (fig.4).

(Fig.7) show the temperature variation of receiver and the three main elements of the exchanger HRSG: evaporator, superheater and economizer. The time, expressed in hours, It was felt here on May 1, We denote these graphs that there is an overall increase in temperature until noon with a decrease until the end of the day. We also note that the temperature of the receiver is significantly higher than for the rest of the other components. This is due to heat loss during the cycle.

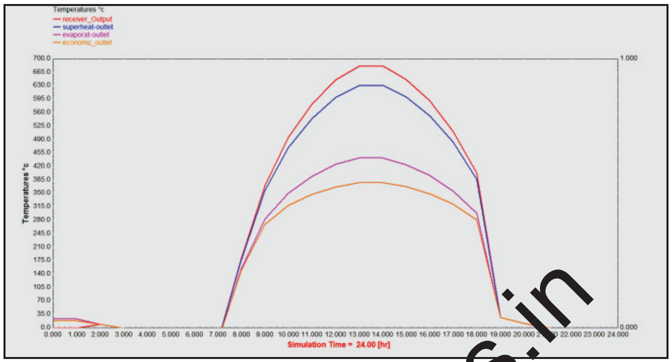

Figure 7.Temperature of the receiver and components of the boiler "HRSG" for May 1st

IV. Conclusion

On the simulation, TRNSYS has much different strength. Firstly a thinner thermodynamic analysis allows the user to know the temperatures, pressures, flow rates and enthalpies at any point in the cycle, and set the system according to its design choices (materials, geometry, performance…). Second, TRNSYS taking into account the inertia of systems and could therefore estimate the performance of the installation in very lower time steps.

Concentrating solar thermal is considered as one of the main options for renewable bulk electricity production. It is expected for the next years a concentrating solar thermal development similar in potential and magnitude to the wind power take-off recently experienced.

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