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New approach of a Conceptual Solar Thermal Steam Generator and its Design &Optimization

Ravikant Bhagat[1]
Electrical Engineering
Guru Nanak Institute Of Technology,
Kolkata, India

Subhadip Kamila[2]
Electronics and communication Engineering
Guru Nanak Institute of Technology
Kolkata ,India

Abstract— **Concepts for solar thermal power systems are based on parabolic trough, tower or parabolic disks either heating molten salts, mineral oil, and air or generating steam. In this research work we propose, a new design approach of a solar steam generator/boiler. We have used a design tool here for optimization of system efficiency considering different subsystem efficiency. This concept comes from the conventional thermal power plants boiler, with the difference that the heat comes from mirrors that concentrate the solar radiation on its external absorbing side at open air, instead of fuel flames heating its internal tube grid. The results of our conceptual design show how much plant performance is achievable, comparable with the most advanced solar concepts. From analysis of this innovative solar boiler applied to electricity production, it is found that overall efficiency of the conversion from direct solar irradiation energy to electricity is above 20%, which is comparable to the value of parabolic trough and central tower technologies. With best of our knowledge, no one has reported this kind of work.**

Keywords—Concentrated solar energy; Solar steam generator; solar thermal; Sustainable development; Solar radiation.

I. INTRODUCTION

Compared to other renewable energy technologies, the solar thermal power industry is a relatively new industry with a limited operational experience. Concentrated solar power (CSP) plants produce electric power by converting the sun's energy into high-temperature heat using various mirrors Configurations to concentrate a large area of sunlight, or solar thermal energy, onto a small area. In this present work a conceptual design of concentrated Solar Thermal Power Plant Using Steam-Generating Solar -Boiler is proposed. The main objective is to design a solar boiler which can produce the required steam for a small scale power generation. This cycle is activated in a central water boiler heated by the oil coming from the solar field [1]. The behaviour of the flow inside the heating tubes can be described as in a combustion boiler with well-known phenomenological correlations as the Lienhard expression for the film heat transfer coefficients (Lienhard, 2006) based on Kandlikar work [2]. One of the possibilities to activate a Rankine steam cycle is to directly generate steam inside the tube of parabolic trough collectors, what increase plant efficiency by eliminating the steam generator required when using other heat transfer fluids. A large experimental facility of this type has been built in Plata forma Solar de Almerıa (Spain) [3]. It is worth pointing out a fundamental point for understanding the moderate values of the radiation losses: currently available coating (used, for instance, in trough collectors' tubes) has a very high solar absorptive and very low thermal emissivity at temperatures below 800 K. In fact, those values can be 0.9 and 0.1, respectively [4]. Electricity generation in solar thermal power plants is a fundamental point in the quest to Sustainable Development [5].As a matter of fact, the heat loads and the temperatures inside the cavity receiver can be too high [6] for the objective of feeding a Rankine steam cycle of standard values. The configuration presented here is based on the structure of coal-fired power plants, where steam is produced in a large array of vertical tubes heated by the combustion products [7]. The behaviour of the flow inside the heating tubes can be described as in a combustion boiler with well-known phenomenological correlations as the Lienhard expression for the film heat transfer coefficients [8] this work is based on Kandlikar work. Mainly depending on the solar light concentration configuration, absorbing collector arrangements, and working fluids, both in the collectors and in the thermodynamic cycle [9]. In particular, the concentration of the solar radiation onto a central receiver mounted at the top of a tower. There are different receiver configurations [10]. The first commercial plant of this technology found in the south of Spain [11]. In a central tower scheme [12] it is important to note that the total collector surface is much larger, in width and height, than the standard cavity receiver. In their study [13] showed that the examined area had a huge potential of Bio-Energy i.e. 81.3 GJ of energy per day or 4065 m^3 of bio-gas per day or 7520 kWh of Electricity per day. In this present study the authors are tried to present a new concept of solar steam generator/boiler design and presented some results which represents its suitability for power generation.

II. METHODOLOGY

A sketch of the solar boiler conceptual scheme is depicted in. *Fig*.1. *the* solar filed is shown in a very simplified style, reducing the technological requirements for the materials maximizing energy and exergy efficiency.In fig.1 different points are showing various parts of the solar boiler like as follows (1) Boiler body, (2) First heating grid,(3) Solar field,

(4) Condensed pump, (5) Recirculation pump,(6) Down pipe,(7) Insulation, (8) Phase separator, (9) Solar boiler outlet, (10)Vapor dryer, (11) Second heating grid, (12) Overheated vapor pipe, (13) Laying of foundations.

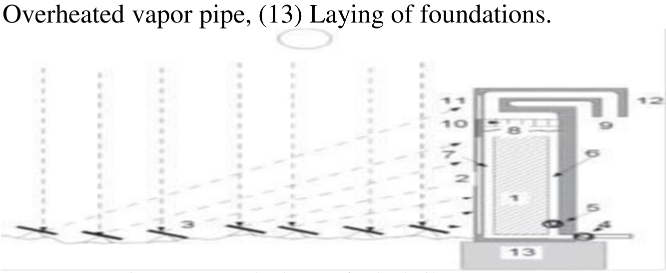

Fig.1Conceptual scheme of solar boiler.

a. Description of a power solar boiler facility

A sketch of a solar boiler for electricity production is shown in Fig. 2, where the boiler coupled to a Rankine cycle.

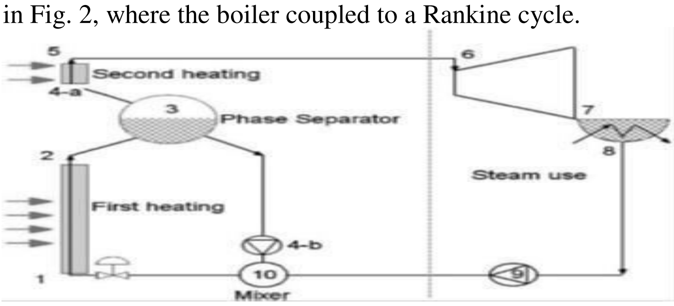

Fig.2 Thermal Schematics of a solar boiler facility.

The main steps in this scheme are: A first heating module (Preheating and boiler), where slightly sub cooled water enters the boiler at point 1, and reaches boiling until a certain vapor fraction at point 2.A phase separator, that removes liquid saturated water (point 4-b) to the mixer and saturated water-vapor (point 4-c) to the second heating phase. A second heating phase (superheating) is there to produce superheated steam at point 5. A steam use phase with the implementation of a water– steam Rankine cycle with classic steam turbines and condenser. In this approach for a general design, we have taken a solar irradiation surface power density of about 74.4 kW/m^2, with an operating pressure of 4 MPa (what implies boiling at 523 K) with a 20% of vapor title at the exit of the boiling section and an overheating of 150 K to obtain the adequate vapor quality at turbine outlet, when the Rankine cycle chosen has two extractions (with iso-enthalpy steps).

III. DESIGN METHODOLOGY

We had tried to concentrate the sun rays on a dual wall glass boiler with an input water flow and output steam flow. The Concentrated rays are used to red heat the steel-wool which is spaced in glass boiler. Within a fraction of time, the water getting heated up and starts generating steam. Here, a conceptual design of a Concentrating solar boiler is proposed. This concept comes from the conventional thermal power plants boiler, with the difference that the heat comes from mirrors that concentrates the solar radiation on a dual wall glass boiler, instead of coming from fuel flames and hot gases. The Boiler that used here should be made of dual wall transparent glass. The transparent glass needed as maximum solar radiation can be entered through the glass wall to heat the steel wool which kept inside the glass boiler for fast and uniform heating of the water. The wall of the boiler is double layered as heat loss though the wall could be minimum. Steel wool is combination of many tiny steel wires that have been pulled through a series of metal dies.

Steel wool has a melting point of 1535^0C and a flash point of 250^0C. The Boiling point of steel wool is 2750^0C.

IV. RESULTS & DISCUSSION

A design tool has been used by which different graphs are drawn for observing maximum temperature difference, energy efficiency along heating and super heating section.Fig.3. Maximum temperature difference between internal and external tubes surface (in blue) admissible by the stainless steel considered (AISI302) and temperature difference for the boiler tubes operating condition (540 K). Fig.4.shows the energy efficiency evolution along the reception surface height. The overall plant efficiency will be a compromise between the solar boiler efficiency, whose tendency will be dominated by radiation losses and decreasing with temperature, these fact implies that the optimal temperature of superheated steam in a solar boiler applied to electricity production should be limited shown in Figs.5 and 6.

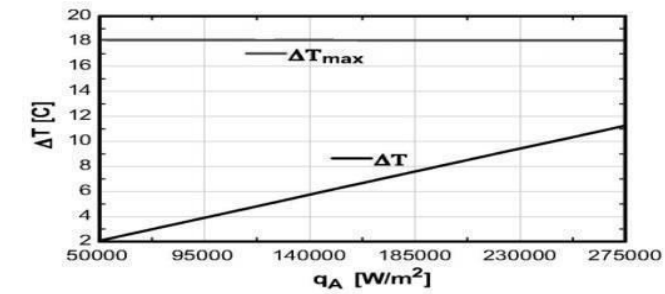

Fig.3 Maximum temperature difference between internal and external tubes surface

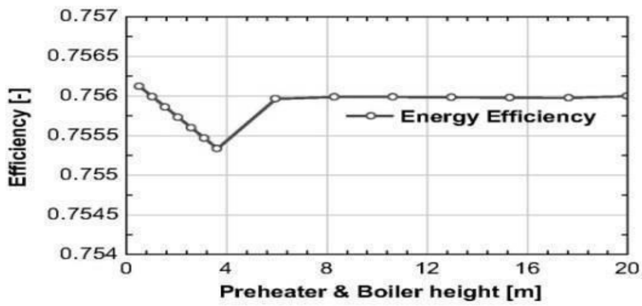

Fig.4 Energy efficiency along the heating section.

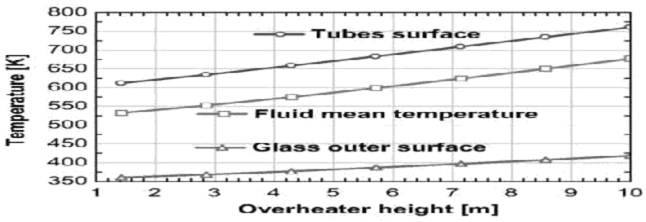

Fig.5 Temperatures along the superheating section.

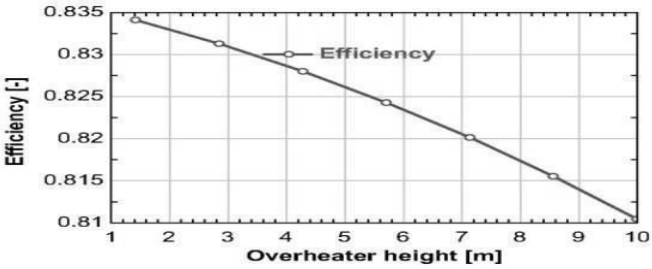

Fig.6 Energy efficiency in the superheating section.

V. CONCLUSION

A new approach of a solar boiler is shown in this paper. This concept comes from the conventional thermal power plants boiler, with the difference that the heat comes from mirrors that concentrate the solar radiation on its external absorbing side at open air, instead of fuel flames heating its internal tube grid. The results of our conceptual design is showing the results of our conceptual design show that plant performance of 20% is achievable, comparable with foreseen figures in the most advanced solar concepts, comparable with the most advanced solar concepts, The main point in our work is related to a better use of the concentrated radiation in order to reduce exergy losses and to maximize total power. For the moment, our analysis points out that the overall efficiency with this concept, for a given radiation field, is higher than the calculated values of other types of solar power plants.

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