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# A thermodynamic model of solar thermal energy assisted natural gas fired combined cycle (NGCC) power plant

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**Abstract**

A solar thermal energy assisted NGCC power plant was modeled to investigate the impact on plant efficiency, output and $CO_2$ emission with solar thermal energy addition. In this particular model, with 23.7 $MW_{th}$ solar thermal energy input to the HRSG, the duct firing could be shut off, 2337.5 kg/h natural gas would be saved, and 6.2 t/hr $CO_2$ emission would be eliminated. However, there would also be a 4.07 $MW_e$ loss in power from the combined cycle. Another solar input approach shows 14.35 MWe additional electricity would be generated with 35 $MW_{th}$ solar thermal energy addition. The thermodynamic analyses in this paper demonstrated the possibilities to utilize the solar thermal energy to reduce fuel consumption and $CO_2$ emission, or to increase the NGCC power plant efficiency and output, while taking advantage of the already existing power plant infrastructure.


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*Keywords:* solar thermal energy; NGCC, hybrid power plant, integrated solar combined cycle

## 1. Introduction

Rapid increase of renewable and clean energy demand in major developing countries of the world such as China, India and Mexico has driven the development of using solar energy, wind and geothermal energy for power generation [1, 2].

Concentrating solar-thermal power (CSP) is proven to have the capability of capturing solar energy and using the captured solar energy to heat a high temperature heat transfer fluid (HTF) [3-5]. It becomes possible to utilize the solar energy to increase the efficiency or increase the output of the conventional fossil-fired power plant. Parabolic

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trough, compact linear Fresnel reflector, power tower and dish-engine are the four existing CSP technologies [6, 7].

Integrating CSP into a NGCC power plant is a way to increasing plant efficiency and output, also decrease the fuel consumption and greenhouse gas emissions [8, 9].

## 2. Model description

### *2.1. Solar collection system*

A CSP collection system was chosen to perform the investigation. In the solar collection system, the HTF will be heated up to 550°C and goes into solar steam generator (SSG) to produce steam. Then, the cold HTF flows back to cold storage tank at 300°C. Table 1 shows the major technical data of the solar collection system.

Table 1. Solar collection system technical data.

| Parameters | Units | Values |
|---|---|---|
| Technology | - | Power Tower |
| HTF type | - | Molten Salt |
| Receiver inlet temperature | °C | 300 |
| Receiver outlet temperature | °C | 550 |
| Thermal collection efficiency | % | 77 |

### *2.2. NGCC power plant thermodynamic model*

The model is using the design data of the NGCC power plant located in Hermosillo, Mexico, which is equipped with a 150 $MW_e$ gas turbine cycle and a 93 $MW_e$ steam Rankine cycle. A Heat Recovery Steam Generator (HRSG) with three pressure levels is producing steam to link the gas turbine cycle and steam Rankine cycle. Table 2 listed the major design data of this NGCC power plant.

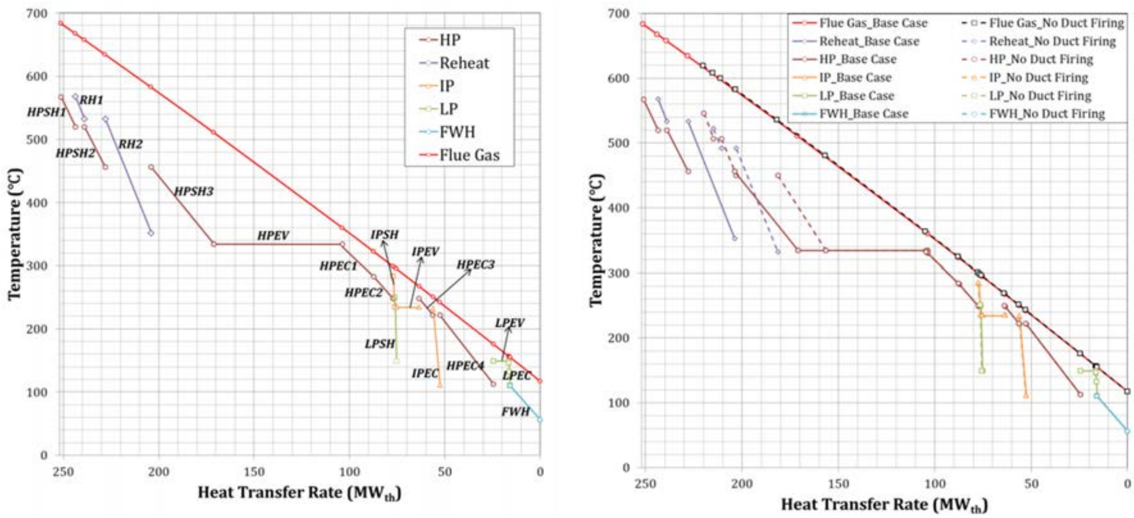


Fig. 1. HRSG Temperature Profiles. (a) left figure for Base Case ; (b) right figure for No Duct Firing Case (Solar Input1).

ASPEN Plus® is a widely used commercial power system process modelling software. The model with design data is as base case in this investigation. Figure 1a shows the heat transferred and temperatures in each component of HRSG (abbreviation definitions in Figure 1a are listed in Appendix Table A1).