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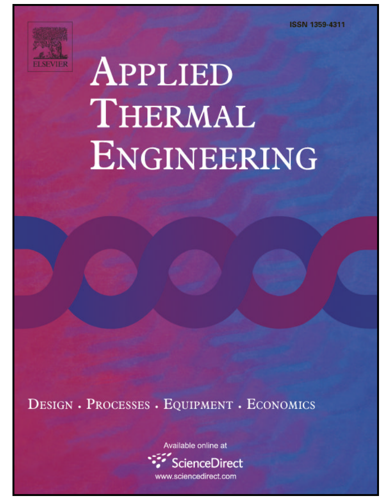

Research Paper

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Power Generation from Fluegas Waste Heat in a 500MW$_e$ Subcritical Coal-Fired Thermal Power Plant Using Solar Assisted Kalina Cycle System 11

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Abstract

This paper proposes a solar assisted Kalina Cycle System 11 (KCS 11) driven by fluegas waste heat of 500MW Subcritical (SubC) coal-fired thermal power plant for additional electrical power generation. A computer simulation programme has been developed in MS-Excel and VBA to calculate and optimize system performance at different conditions. Results show that net electric power generation of about 516.52 kWh can be added with main plant generation for improving the plant net energy and exergy efficiencies by about of 0.040 % and 0.036 % point, respectively. This will reduce the annual CO_2 emission by about of 1008.28 t. Solar assisted KCS11 is more energy efficient and less exergy efficient compared to standalone KCS11. About 0.76 is the optimum ammonia mass fraction that yields the maximum efficiency at the operating pressure of 17.54 bar. System performance increases with increase in cooling water flow rate and optimum at 92.80 kg/s. Power generation cost and payback period of the proposed system are about of Rs. 2.163 per unit and 12.44 years, respectively. The levelized cost of excess electricity (LCoE) generation by solar heater is about Rs. 10.99 per kWh which is about 8.80 % lower than conventional solar thermal power plant.

Keywords: Exergy; Economic; Fluegas waste heat; Kalina cycle; Solar energy; Thermal power plant.

1. Introduction

Day to day, the extensive consumption of energy in general and electricity in particular is increased for maintaining the sustainable economic growth of any country. Energy related CO_2 emissions are expected to rise by more than 40% by 2030 as the projection of global energy consumption will be increased by 71% [1]. Depletion of fossil fuels for thermal power generation and its detrimental effects on the environment put the energy researchers to a great challenge for mitigating rising problems. In conventional coal-fired steam power plants, fluegas loss of about 5% is occurred at 413.74 K. For avoiding acid corrosion due to sulphur dew point temperature and to maintain the highest performance level of electrostatic precipitator (ESP), fluegas temperature is normally required of about 402 K at ESP inlet. Plant has been designed its value at 413.74 K at air-pre heater (APH) outlet by considering different plant operating conditions such as service condition of high pressure heater (HPHs), amount of air leakages in APH and heat loss from the fluegas duct in between APH and ESP. During plant normal operating condition, the surface heat loss of flugas duct causes the temperature fall by about 15 K. This may cause due to wind velocity, poor insulation of fluegas duct and etc. By caring this matter in view, fluegas stream temperature of about 413.74 K at APH outlet can be utilised for additional electric power generation. During last few decades, various thermodynamic cycles have been proposed by different researchers to produce electric power from different grade of waste heat from different sources [1,2]. X. Zhang et al. [3] compared the performance of different power cycles for waste heat steam and concluded that S-ORC (Steam-Organic Rankine cycle) system has better matching of heat source temperature and each power cycle is optimal at different temperature range. M. Aziz et al. [4] has shown the energy efficient utilisation of both solid and liquid waste from palm oil mills and cyclohexane has higher energy efficiency compared to toluene and n- heptanes in ORC module. M. Areke et al. [5] proposed a system for generating electric power in food processing application and they concluded that the proposed system will meet daily power requirement and 98.5% of daily peak requirement. Organic Rankine Cycle (ORC) has poor overall efficiency [6] for waste heat recovery system at moderate temperature where as the Kalina cycle is one of the suitable efficient technologies for power generation from low-grade waste heat [7]. Khankari and Karmakar [8] proposed a Kalina cycle system to utilise the coal mill rejection from a coal-fired power plant for generating additional electric power of about 562.75 kW. In literature, some of the research papers [9,10 &11] developed a general code to calculate thermodynamic properties of working fluid related to ammonia-water Kalina cycle and optimise the system performance. C.E.C.Rodriguez et al. [12] also showed the exergetic and economic comparison of ORC and Kalina cycle for low

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