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A techno-economic analysis of partial repowering of a 210 MW coal fired power plant

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Abstract. This paper presents a techno-economic analysis of a partial repowering scheme for an existing 210 MW coal fired power plant by integrating a gas turbine and by employing waste heat recovery. In this repowering scheme, one of the four operating coal mills is taken out and a new natural gas fired gas turbine (GT) block is considered to be integrated, whose exhaust is fed to the furnace of the existing boiler. Feedwater heating is proposed through the utilization of waste heat of the boiler exhaust gas. From the thermodynamic analysis it is seen that the proposed repowering scheme helps to increase the plant capacity by about 28% and the overall efficiency by 27%. It also results in 21% reduction in the plant heat rate and 29% reduction in the specific CO2 emissions. The economic analysis reveals that the partial repowering scheme is cost effective resulting in a reduction of the unit cost of electricity (UCOE) by 8.4%. The economic analysis further shows that the UCOE of the repowered plant is lower than that of a new green-field power plant of similar capacity.

Keywords: partial repowering; gas turbine; feedwater heating; specific CO_2 emission; cost of electricity

1. Introduction

Rapid industrialization and socio-economic growth is expected to dominate most parts the globe, especially the developing countries like India and China. World energy consumption is projected to increase by 56% by 2040 (International Energy Outlook 2013). Electricity is one of the major modes of energy consumption. 40% of the total worldwide electricity is generated from coal (International Energy Outlook 2013) and coal combustion results in huge amount of green house gas (GHG) emission into the atmosphere. Reduction in GHG emission from the fossil fuel based power plants is a major issue throughout the world nowadays because global carbon dioxide emission is projected to rise by 46% by 2040 (International Energy Outlook 2013). The necessity to satisfy the thirst of growing energy demand, coupled with different social and political issues associated with the construction of new power plants, has put renewed focus on repowering of old

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existing coal fired power plants to boost up their performance characteristics by enhancing the capacity, efficiency and by reducing GHG emissions in an economical way. Repowering can be done by various ways. Wolowicz *et al*. (2005) showed that improvement in power output and efficiency of a super critical power plant by 20% and 1%, respectively can be done by feedwater repowering using hot exhaust gas from a gas turbine (GT). Escosa and Romeo (2009) showed that 15% CO_2 emission reduction and 2.61% efficiency improvement of an existing power plant can be done by feedwater repowering whereas 23.17% CO_2 emission reduction and 3.62% efficiency improvement of the same existing plant can be done by parallel repowering by integrating GT with the existing plant. Karellas *et al*. (2012) made energetic, exergetic and economic analyses of feedwater repowering using GT exhaust and parallel repowering by GT and heat recovery steam generator. Carapellucci and Giordano (2013) made energy and economic performance analyses of feedwater repowering of an existing coal based power plant. A further study of the same author (2014) evaluated the effects of feedwater repowering operating conditions on energy, environmental and economic performances of a 600 MW coal fired power plant at different condenser overloads and boiler modes of operation. Tawfik and Smith (2010) addressed that hot windbox repowering and combined cycle repowering of an existing unit helps to increase in output by 49.2% and reduction in heat rate by 11.6%. Yilmazoglu and Durmaz (2013) showed that increase in net power output by 27% and decrease in specific CO_2 emission can be done by hot windbox repowering of a thermal power plant. Repowering by GT exhaust reburning in a combined cycle helped to increase the capacity and efficiency of Goi Thermal Power Plant the plant by 36% and 7.8%, respectively (Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, 1996) Tucakovic *et al*. (2013) investigated the reconstruction of boiler of existing steam power plant for using GT exhaust by means of thermodynamic and economic analysis. Xu *et al*. (2013) addressed the effect of flue gas waste heat recovery on net work output and coal consumption of a typical 1000 MW coal fired plant in China. So it is seen from the above literature survey that various researcher have made investigation of repowering of existing power plant by using GT in different ways.

In this paper, a techno- economic analysis of a partial repowering scheme for an existing coal fired power plant, through GT integration and feed water heating using boiler exhaust, is reported. In this scheme, out of four coal mills, one mill is taken out from the existing boiler and equivalent energy is supplied by sending the GT exhaust into the furnace of the existing boiler. The residual oxygen content in the GT exhaust takes part in the combustion of coal, thereby reducing the boiler's secondary air requirement. Along with this, waste heated feedwater heaters are proposed to be installed after the existing air preheating section of the boiler for feed water heating by utilizing the waste heat of the flue gas coming out from the repowered plant's boiler.

2. Existing plant description

The schematic diagram of the existing plant is shown in Fig. 1. Here a 210 MW thermal power plant is considered. The figure shows all the major components of the plant and their configuration. The coal is burnt in the furnace (CC), and then the hot flue gas goes to the stack through induced draft fan (ID Fan) exchanging heat at evaporator (EVP), superheater (SPH), reheater (RH), economizer (ECO) and air pre-heater (APH) sections of the boiler. The forced draft fan (FD Fan) supplies the air, preheated at the air pre-heater (APH), to the furnace. The generated steam from the boiler is expanded high-pressure turbine (HPT), intermediate pressure turbine