Maximization of Net Output for Boundary Dam Unit 3 Carbon Dioxide Capture Demonstration Project

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Abstract

Boundary Dam Unit 3 Carbon Dioxide Capture Demonstration Project (BD3 ICCS) is well known as the first commercial CO_2 capture and storage integrated to a coal fired power plant with the production rate of 110 MW. This project transformed the aging Unit 3 at Boundary Dam Power Station into a reliable, long-term producer clean base load electricity, while demonstrating EOR potential for a fully integrated process. During the design process, not only the reliability of the CO_2 capture plant but also the power production rate was concerned. Without CO_2 capture, pre-upgraded BD3 produced 150 MW gross output which accounting for net output of 139 MW. The CCS facility requires steam for solvent generation and electricity or CO_2 compression as well as other additional auxiliary loads therefore the net output is decreased with the integration of CCS. Initial models incorporating CCS calculated a net power output of 85.95 MW. However, it was noted that for this initial model some auxiliary loads had not been considered (such as electricity for service and maintenance). Consideration of these inputs further reduced the net output to 80.95 MW. Resulting energy penalty is of most concern when integrating CCS into a power producing facility. The initial models generated in this study indicated a reduction in net output of approximately 42% - an unfavorable value. This paper reveals the optimizing, retrofitting and upgrading options have been investigated in order to maximize the net output during the design process of BD3. Several factors have been taken into consideration including technology for CO_2 compression, turbine refurbishment, steam extraction and optimization, flue gas cooler

(FGC) installation for heat recovery, main steam temperature, boiler refurbishment and others. This paper will present the analysis of each aspect in detail.

Several options and equipment vendors were investigated for the CO_2 compression process. The first option explored using a CO_2 compressor that was low cost and generated a substantial amount of heat during the compression which providing an opportunity for heat recovery. Based on the initial design, the compressor consumed up to 20.79 MW. This compression power seemed high but could be mitigated for through heat recovery application. However, our engineering team decided not to continue further with heat recovery from the compressor. Instead, a compressor with lower energy consumption but with higher equipment cost was selected. The selected compressors consume 13.74 MW. The source of steam used for solvent regeneration is believed to be an influential factor for the reduction of electrical output of the power plants. Therefore, it was investigated intensively in this study. Gatecycle software was used to predict how the power plant performing when steam was extracted to supply CCS process.

Several models were produced to estimate the cost of steam which is the ratio between power loss per thermal energy withdrawn from the steam cycle. The available energy from the flue gas was recovered and used for condensate preheating. Five positions of steam extraction including hot reheat, hot reheat with back pressure turbine, IP-LP crossover, mixture of IP-LP with cold reheat, mixture of IP-LP with IP extraction were investigated. The cost of steam for different steam extraction is shown in Figure 1. The results showed that the extraction steam from IP-LP crossover providing the lowest cost of steam among the others. Moreover, extraction steam from IP-LP crossover is more promising when considering capital cost of turbine modification. The detail for turbine refurbishment, flue gas cooler (FGC) installation for heat recovery, main steam temperature, boiler refurbishment and others will be discussed in the paper.

The final integrated model produced a net output of 110.88 MW – a 29.93 MW increase when compared to the initial cases as shown in Figure 2. Figure 3 shows the summary of the contribution of each factor to the improvement of the 29.93 MW gross output. 24 % net output improved from the based case came from the selecting to optimum technology for CO_2 compression. The refurbishing of the turbines contributed to 20 % of the net output increasing due the elimination of turbine leakage. The recovery heat from flue gas by using FGC and used for condensate preheater increased the net output another 13 %. The increase of the main steam temperature and boiler refurbishment increase the net output of 7% and 5% respectively.

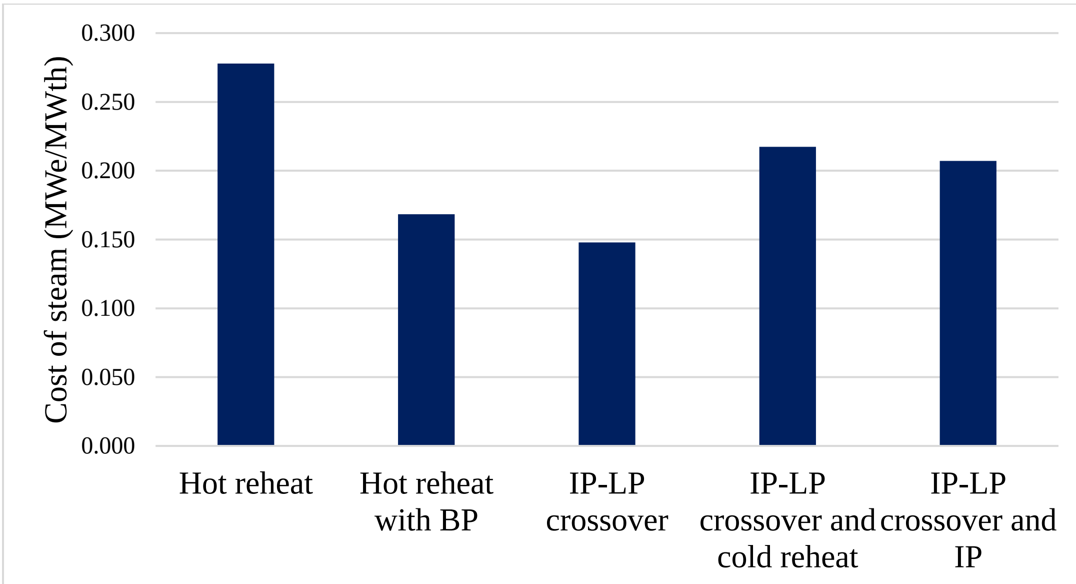

Figure 1. Cost of steam at different extraction

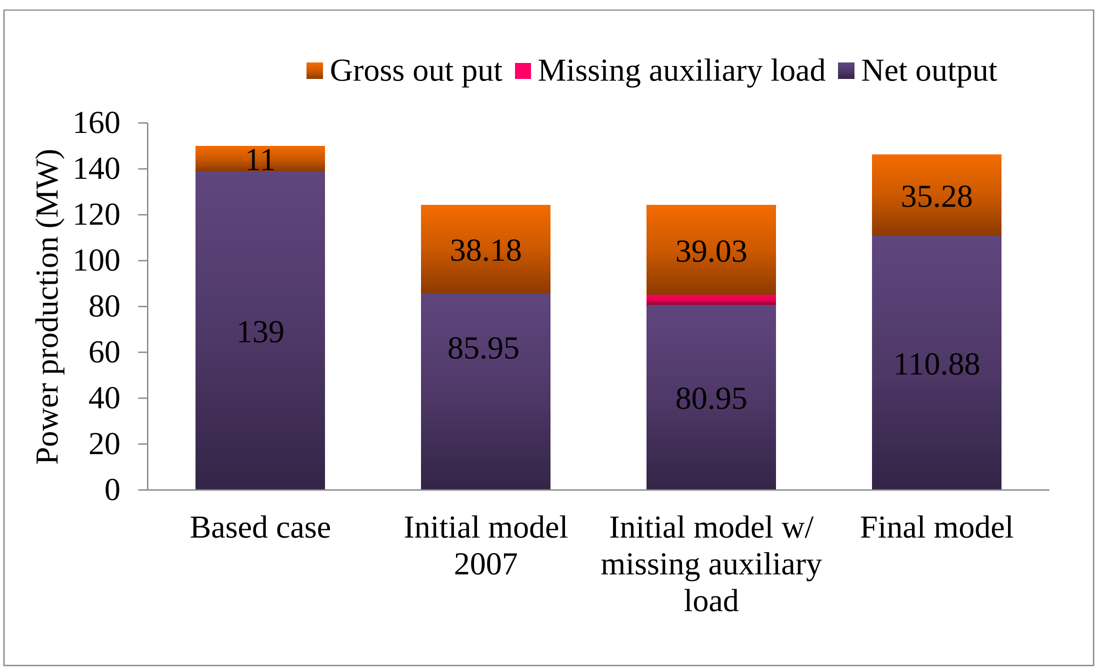

Figure 2. Improvement of net output during the CCS design process

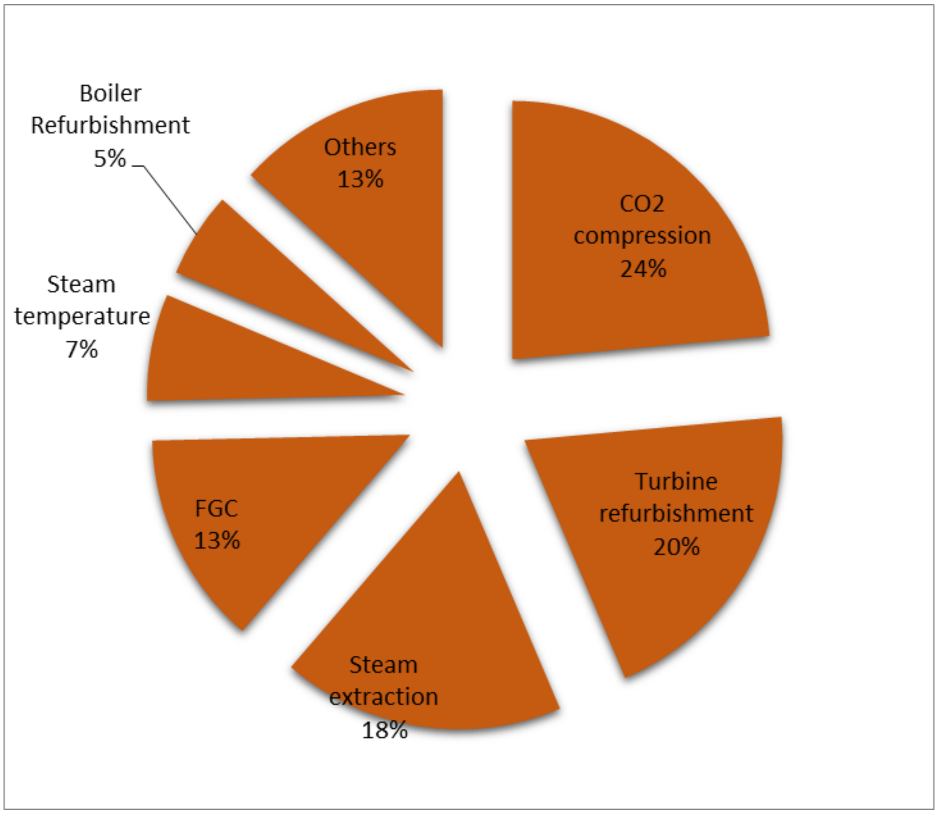

Figure 3. Net output percent increase corresponding to selection factors