



Heat Integration Analysis and Optimization for A Post Combustion CO₂ Capture Retrofit Study Of SaskPower's Shand Power Station

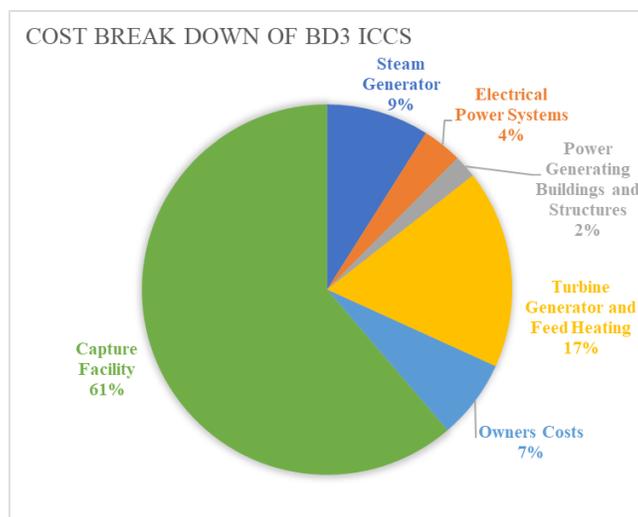
Stavroula Giannaris¹, Brent Jacobs¹, Wayuta Srisang¹, Corwyn Bruce¹, Dominika Janowczyk¹

¹The International CCS Knowledge Centre, 198 – 10 Research Drive, Regina, Saskatchewan
Canada S4S 7J7

Abstract

Thermal energy is necessary for amine regeneration in post combustion CO₂ capture processes. The source of this energy (in the form of steam) dictates the success of a post combustion carbon capture facility. In coal fired power stations, steam can be extracted from within the steam cycle – resulting in a power production penalty. Heat integration is the study of minimizing energy consumption while maximizing heat recovery. Heat integration provides the foundation for successful CCS retrofits. In October 2014, the World's First Integrated Carbon Capture Facility went on line. Various modifications to the turbine and feed heating system at BD3 contributed greatly to overall project costs (Figure 1).

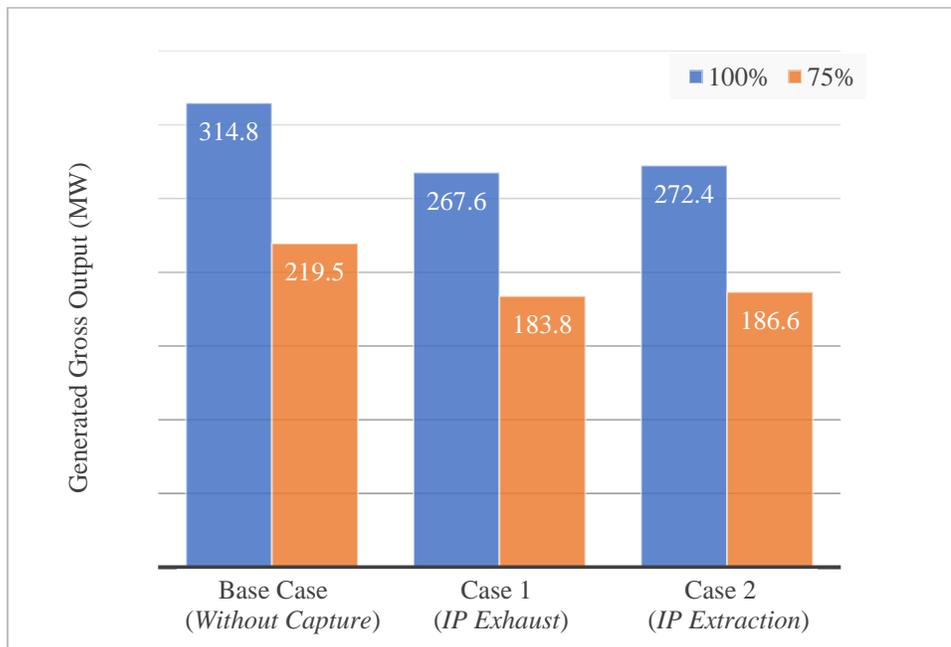
Figure 1. Cost Breakdown of BD3 ICCS



SaskPower’s Shand facility is a 300 MW, single unit, coal fired power plant producing approximately 1,100 kg of CO₂/MW-h. Shand has double the capacity of SaskPower’s Boundary Dam Unit 3 (BD3 ICCS), making it an ideal candidate for CCS application on an even larger scale. Heat integration analysis of the existing steam cycle at Shand was conducted using Gate Cycle™. A baseline model was initially built using Shand’s Heat Balance. Configurations of steam extractions to the deaerator (DEA), extractions to the reboiler, and utilization of a flue gas cooler (FGC) working in conjunction with a condensate pre-heater (CPH) were investigated at 100% and 75% loads. Investigating various modifications to the feed heating system avoids costly custom turbine modifications (as was done with BD3’s turbine).

The extraction to the reboiler was taken from the IP-LP Crossover. The FGC and CPH were consistently run in conjunction with steam extraction to the reboiler to reflect the actual changes imposed on the steam cycle with CCS online. The pressure of the DEA was increased by changing its steam source from the original positioning at the LP turbine, to the IP exhaust, and finally to the extraction line from the IP to FWH5. Once again, each case was evaluated at 100% and 75% loads. High pressure condensate preheating (although a valid option) was not investigated in detail due to higher pressure requirements in the feed heating system, increased heat quality needs, and overall increased complexity.

Figure 2. Comparing Generated Output Between Cases at 100% and 75% Loads

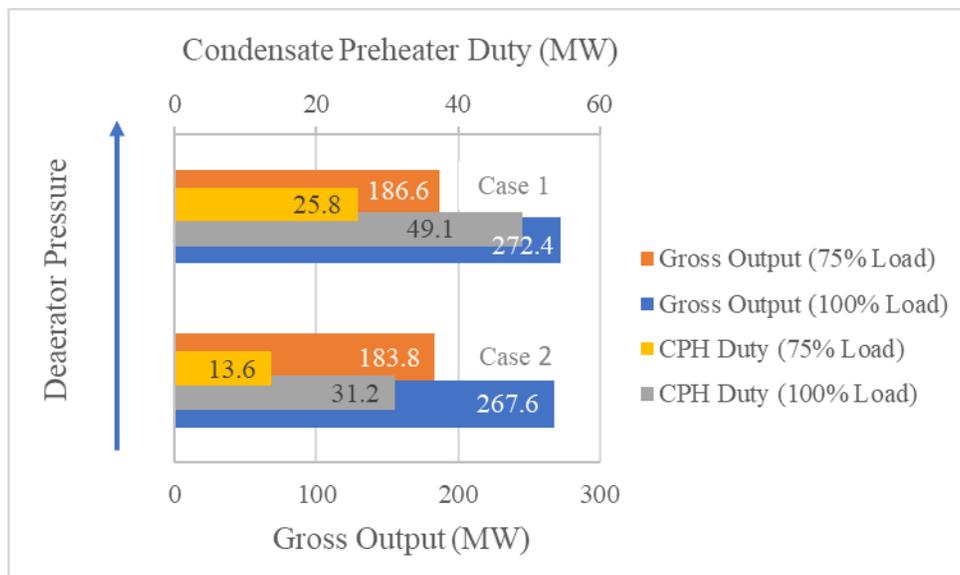


Losses to overall power output are significant to a utility producing company. As seen in Figure 2 the location of the steam extraction to the DEA is significant. The steam extraction to the reboiler was taken from the IP-LP crossover as it provides the lowest cost of steam for the process.

Case 1 was modelled to reflect the decision to keep the current LP feed heating system and avoid replacement costs. The DEA pressure was set to its current design values for the 100% and 75% cases. The DEA extraction was taken from the IP exhaust. Using an iterative process, the maximum amount of condensate preheating was found assuming a minimum 15-degree temperature rise between the temperatures of the condensate stream and the DEA. *Case 2* was modelled with the extraction to the DEA from the IP allowing for a higher extent of condensate preheating. Once again, a 15-degree temperature rise between the temperatures of the condensate stream and the DEA was maintained and the model was optimized.

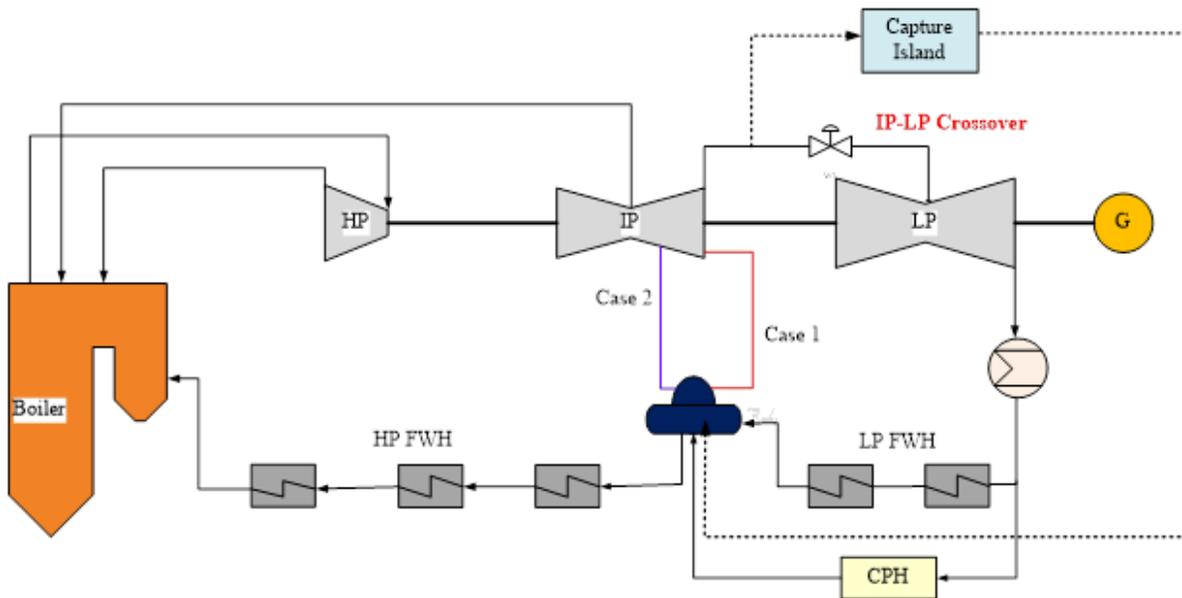
The extraction to the DEA from a higher-pressure steam source serves to increase the operating pressure of the DEA (Figure 3). This increase in pressure is required to increase the temperature at the deaerator. These changes to the DEA facilitate a greater extent of condensate preheating, better utilization of “waste” flue gas heat, and an overall decrease in the output penalty to the plant (Figure 3).

Figure 3. Effects on the Steam Cycle with Increasing Deaerator Pressure



Modifications to the steam cycle also included the insertion of a butterfly valve in the IP-LP crossover (Figure 4). Changing the pressure at the back end of the IP turbine changes the pressure ratios within the last stages of the IP turbine, subsequently leading to changes in the volumetric flow rate (impacting turbine efficiency and stresses). Traditionally, butterfly valves are often employed to maintain the pressure at the back end of the IP turbine as to avoid costly modifications to the turbine itself. In the intended design of Shand's steam cycle, the butterfly valve remains fully open at full load. At reduced loads, however, the butterfly valve functions to control supply steam at a high enough pressure to continue capture operations by throttling the flow of steam. This concept was demonstrated in Gate Cycle™.

Figure 4. Steam Cycle Configurations for Reboiler and DEA Extractions



CPH is limited by the quantity of heat to the DEA. An increase in DEA pressure facilitates an increase usage of condensate preheating. This increased potential to utilize more heat from the flue gas for condensate preheating improves over all heat integration and increases overall output. Further increasing the DEA pressure to optimize the CPH loop would be limited by the design pressure of the DEA. Beyond this point economics would be considered in replacing the existing LP feed heating system to facilitate further increases to DEA pressure and utilization of the CPH.

Flue gas entering the carbon capture island must be cooled and enter the capture facility at a desired temperature (dictated by the capture facility's operating parameters). This rejected heat is integrated back into the steam cycle by introducing a CPH loop. This eliminates the need for LP feed water heaters. As indicated in Figure 5, an increase in FGC duty correlates to an increase in output. The more heat that is extracted from the flue gas and used towards condensate heating, the less steam is required for extraction to the DEA and the feed water heaters.

Figure 5. Comparing Gross Output with FGC Duty for 100% and 75% Load

