



Shand Coal Fired Power Plant Integrating a Post Combustion CO₂ Capture Process

Dominika Janowczyk¹ Wayuta Srisang¹ Teerawat Sanpasertparnich² Brent Jacobs¹
Stavroula Giannaris¹ Corwyn Bruce¹

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

² Stantec, 400-1820 Hamilton Street, Regina, Saskatchewan, S4P 2B8, Canada

Abstract

The energy penalty and its associated costs are of major concern for power producing companies considering the application of carbon capture and storage (CCS) technologies for mitigation of CO₂ emissions. Two main approaches for lowering this energy penalty are: (1) Development of low energy requirement CCS technologies and (2) Optimization of the steam cycle to minimize the impact of the energy use on the plants power output. Much academic research has been focusing on CO₂ capture technologies improvement, however, steam cycle optimization requires expertise from an industrial standpoint. Major modifications are required when conducting process integration between a coal fired power plant and a CCS facility. These changes include extraction of process steam for solvent regeneration and cooling of the flue gas to facilitate CO₂ capture process (particularly with heat sensitive amine based CO₂ absorption solvents). Furthermore, if economical, the heat removed from the flue gas can be utilized for condensate preheating via a flue gas cooler (FGC).

Main objectives of this work involved evaluating the thermodynamic performances of the integration of a CO₂ capture process for SaskPower's Shand Power Station – a coal fire power plant with a gross capacity of 306 MW. Various scenarios were explored in optimizing the process. Performance was compared between cases. Cases included exploring the benefits of additional stages in the IP turbine with reduced crossover pressure versus the benefits from utilizing a back-

pressure turbine. Simplified diagrams of the steam cycle with addition of IP stages and utilization of back- pressure turbine are illustrated in Figure 1 and 2 respectively.

Shand power station is a sub critical coal fired power plant located in Saskatchewan, Canada. Shand power station consists mainly of a boiler for steam generation, a turbine which includes a high pressure (HP), an intermediate pressure (IP), and a low pressure (LP) turbines, a condenser, a deaerator and a feed water preheater train. The feedwater preheater train includes two low pressure feedwater heaters (NO.1 LP and NO. 2 LP) and three high pressure feedwater heaters (NO. 4 HP, NO. 5 HP, and NO. 6 HP). The existing Shand power plant withdraws steam from the LP turbine to the deaerator for removal of oxygen and other dissolved gases from feedwater.

Gatecycle™ is a commercially available heat and mass balance software which was used to simulate this work. Its capacity includes modelling steady state design as well as off-design performance of thermal power plants. During the simulation process, the Maximum Design Flow (MDF) without steam extraction was simulated as a base case. Using a heat balance the base model was built and run in design mode (Geometry mode) which allowed Gatecycle™ to size the equipment. Then, the effects of steam extraction were investigated by running different scenarios in Off Design (performance) mode which determine how the turbines would react to the altered steam flow from steam extraction. Several modifications to the steam cycle configuration were evaluated in order to investigate the effects of additional stages in the IP turbine, and the back-pressure turbine. All scenarios were then analysed based on the assumptions of 53 MWth heat recovery from flue gas cooling and a constant heat rate to the CO₂ reboiler.

Ideally, process steam for a post combustion capture process should be extracted from the steam cycle at the lowest pressure adequate for solvent regeneration. This helps to minimize the loss in power generation. Extracting process steam from the IP-LP crossover results in reduced pressure in the crossover but also causes increased stresses and reduced efficiency in the last stages of the IP turbine. A valve can be installed in the IP-LP crossover to maintain pressure at the exhaust of the IP turbine, but throttling of the crossover steam flow through this valve results in losses. If the process steam is extracted from the turbine at a pressure higher than what is required by the capture process, a back-pressure turbine can be used to reduce the pressure of the steam while also generating additional power in the process.

Figure 3. compares the gross output of each scenario. As indicated by the results, addition of a back-pressure turbine contributes to a 6.2 MW improvement in gross power output. The effect of increasing the number of IP stages can be understood when comparing the gross output of the Base Case, Case 2 and Case 3. The increase of IP stages from four to six contributed to an increase of 13.6 MW gross output. Moreover, a steam path upgrade allows for the recovery of efficiency losses from degradation of the existing turbine and the application of new turbine technology. The existing steam path can be modified by replacing one or more of the turbine blade stages and inner casings, without changes to the outer casing or connecting piping. Such a change can allow for the addition of extra stages in the IP turbine improving the efficiency and allowing the pressure at the crossover to be optimized for the capture process requirements. Upgrades to the steam path require minimal on-site labour and construction. Although a back-pressure turbine adds the possibility of increased efficiency, the installation of one can be very costly. With modifications to the turbine and steam path we can approach this increase in efficiency. With the added advantage of keeping the outer casing and associated equipment this option can compete with or even be less expensive than adding a back-pressure turbine.

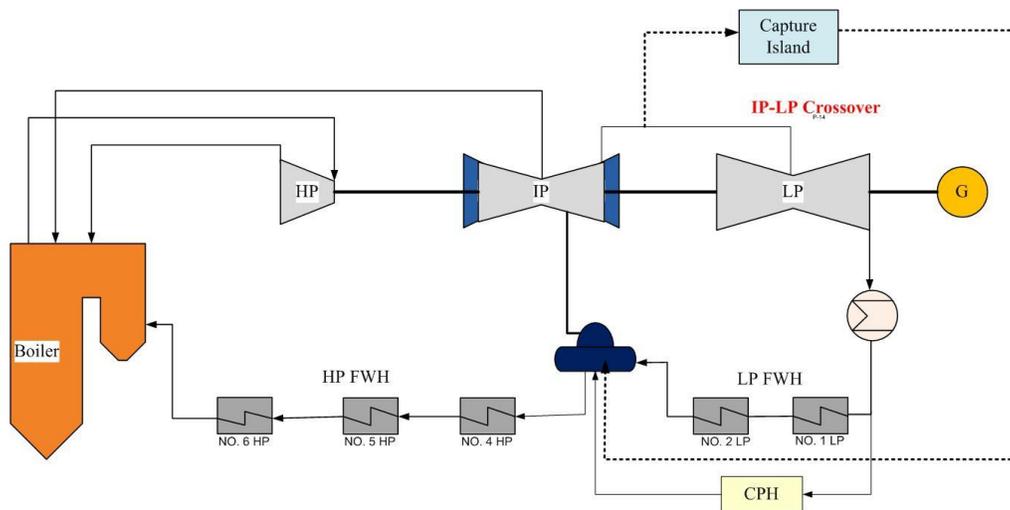


Figure 1. Simplified diagram of Shand power island retrofitted with CCS

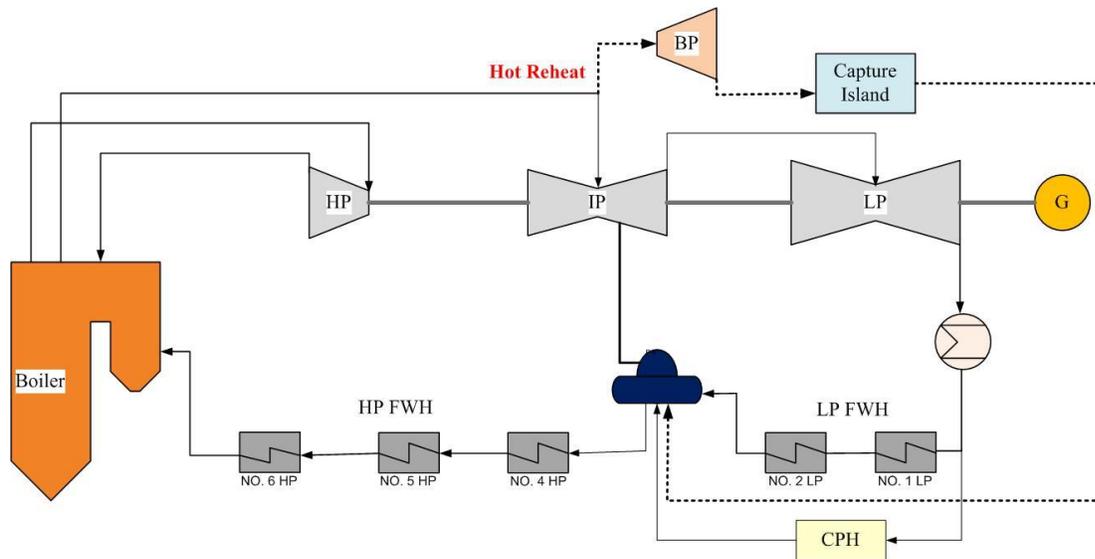


Figure 2. Simplified diagram of Shand power island retrofitted with CCS and equipped with back- pressure turbine

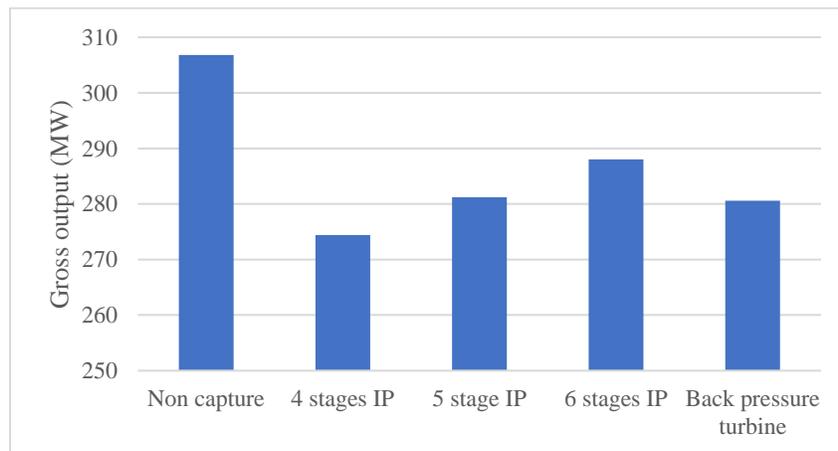


Figure 3. Comparing gross output for different steam cycle modifications