System Modelling of a 50MWth Demonstration Flameless Pressurized Oxy-Combustion Pilot Plant

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Abstract

Flameless Pressurized Oxy-combustion (FPO) technology, developed by ITEA, is providing a pathway for thermally and economically efficient coal combustion with carbon capture and storage (CCS). The technology is being developed into a 50 MWth scale firing loop which will bring the technology maturity closer to a full-scale commercial power plant. As part of the development process, the FPO cycle is modelled in Aspen plus by Southwest Research Institute (SwRI). The model is adapted to match experimental data taken by ITEA on a smaller firing loop.

The combustor operates separately at a temperature of 1650 K. The combustion gases are mixed with a portion of the recycle gas, quenching the flow down to 1093 K. The combustion loop is maintained at a pressure of 12.2 bar. The gas that is not recycled is removed from the loop at high temperature before the boiler. This gas is expanded down to 2.4 bar with a turbo-expander that provides additional power generation. After this point, a scrubber and condenser remove SO\textsubscript{2} and water from the gas stream. This results in a gas stream that is almost entirely made up of 94% CO\textsubscript{2} by mass with 95.5% O\textsubscript{2} purity. The purity of the gas stream and the absence of large particulates eliminate many purification components required for post combustion CCS and improves the cost and efficiency of the overall cycle.

The 50 MWth cycle model is tested with varying input conditions. Coals of low rank, including PRB and Lignite coals, are fed into the system. For the different coals, adjustments are made to the flow splits and feed rates in order to maintain the 50 MWth of produced energy. The different coals are compared to each other in terms of their feed requirement relative to thermal output, their efficiency, and their CO\textsubscript{2} production.

One of the candidate installation sites for the 50 MWth pilot demonstration plant is a combined heat and power (CHP) application. The cycle model is modified to add the flexibility to produce steam for distributed heating during the colder months and power during the warmer months. The power is produced by a back-pressure steam turbine that can accept a flexible load. The steam is produced by a novel once-through steam generator (OTSG) that channels the pressurized flue gas through a pressure vessel containing a network of steam tubes. The steam is provided at supercritical temperatures and pressures to demonstrate viability for supercritical steam turbine at the commercial scale. The steam pressure is then dropped to meet CHP requirements.

The 50 MWth cycle model is adapted into a fully commercial model that fires at 1,500 MWth. This arrangement is laid out in a modular configuration which requires three separate combustor-boiler
loops. This cycle includes a supercritical steam turbine operating with a single stage of reheat. The power produced by the turbine and the turbo-expander is calculated and offset by the expected parasitic loads from the compressors, blowers, and other parasitic power losses. A comparison of the net produced power for different qualities of coal feeds is made.