Simulation and Optimization of a Steam Co-generation Plant with Integrated Bio-ethanol Production

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Second generation bioethanol production is often favored over first-generation as it decouples food and energy production. It is as well considered a more sustainable way of using biomass for energy purposes than combustion as it sustains and recycles the potassium contents. The aim of this project was to implement second-generation bioethanol production in existing thermal power plants to reduce the costs of producing sustainable biofuel for the transportation sector while at the same time increasing the flexibility of the plants' electric power production, allowing for higher levels of renewable power penetration in the grid.

The project focused on a thermodynamic optimization of integrating second generation bioethanol production based on straw in the combined heat and power production at existing power plants. The basis is the combined heat and power plant Avedøreværket 1 (AVV1) and a biorefinery based on the IBUS (Integrated Biomass Utilization System) process with wheat straw as feedstock.
Models of both AVV1 and the IBUS plant were developed in the simulation program Dynamic Network Analysis. The AVV1 model deviations were in the range of up to 4% on all parameters, with a special electricity production deviation at Benson minimum load of +10%. The bioethanol production, CO_2 generation and the water consumption at the IBUS plant are all within the ranges presented in literature.
The IBUS plant feedstock upland was determined by an economy of scale estimation, stating a maximum feedstock transport distance of 50km. Based on the feedstock upland size and numbers on agricultural practices from Danmarks Statistik, the process capacity of the IBUS plant was dimensioned to be 22.4ton/h, equaling a heat consumption of 48.4 MJ/s.
An exergy analysis is used to determine the thermo-energy optimal extraction point of steam from AVV1. For indirect use of the extracted steam, the Intermediate Pressure 2 (IP2) turbine inlet is best suited, while for direct use of the extracted steam, the first extraction point at the Intermediate Pressure 1 (IP1) turbine is best suited. The electricity production of AVV1 is given an extra flexibility of 6.2-6.9MW for the first option depending on the operation mode, and 6.0-6.6MW for the second option.
An economic analysis of using extracted steam for an IBUS plant rather than using a gas fired boiler is yet to be finished, but present results suggests a reduction in operation cost of 10-45% for an integrated plant compared to the 'stand alone' scenario.

Many studies have pointed out the increased sustainability in processing straw in an IBUS facility prior to combustion rather than using it for direct combustion in thermal power plants. This study shows that an integration of an IBUS plant at a thermal power plant can reduce the operation cost of the IBUS production markedly, while at the same time increasing the electric power flexibility of the power plant. The latter ability will become increasingly important in the nearest future as the newly set governmental target of 50% wind power penetration in the grid will challenge the power production at thermal power plants even further.