ABSTRACT

Energy analysis of a power plant with flexible hydrogen output and carbon capture for lower environmental impact

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CO_2 mitigation is a major challenge of today's scientific community in light of the rising CO_2 concentration in the atmosphere that can be attributed to human activity. Faced with these issues, the reduction in CO_2 emissions is up most important. Several methods were proposed in the literature either by improving high CO_2 emitting plants or by alternative, more environmental-friendly technologies. Steam methane reforming is the main technology used to obtain hydrogen, a technology that produces a significant amount of carbon dioxide as side product in the process. Dry methane reforming (DMR) is a promising technology that has the potential to replace the technology that is used in the present. DMR uses CO_2 instead of water for the reforming process, presenting a good use for the obtained greenhouse gas (CO_2) from the production process. With the rise of renewable energy sources, energy production values started to significantly differ during a 24 h period. Classical power plants may not be able to balance a sudden increase in demand and this calls for power plants with a higher degree of flexibility. To be able to face sudden increases in demand, power production has to be increased. A similar issue arises with sudden drops. Production has to be lowered to lower overproduction. A low overproduction margin equals lower CO_2 emissions. During low power demand, the surplus of energy can be stored in the form of hydrogen and during high demand the stored hydrogen can be fed to the gas turbine to produce power. The produced hydrogen can also be sold as a chemical. Flexible hydrogen and power production is a promising technology that could also help to better maintain a balance in the power grid. In this work, energy and exergy analysis is applied to better understand, assess and further improve dry methane reforming for its application in a flexible power plant producing power and hydrogen.

The proposed power plants' production is about 500 MW net with the possibility of producing 200 MW hydrogen (based on the lower heating value). The CO_2 capture rate is at 90 % using MDEA liquid adsorption. The reforming unit is modeled on the kinetics found in the literature. For power production, a Mitsubishi Hitachi Power Systems M701G2 series combined cycle gas turbine was considered. The surplus of CO_2 produced in the system is sent to a storage facility.

Results show there is potential for improving the technology, to make it more energy efficient, especially in the case of the steam turbine where the off gasses heat is recovered. A significant amount of energy can also be recovered in the cooling section of the syngas. This energy can be used to heat the feed stream of the reactor. Similarly, the heat generated in the water-gas shift reactors can be used for the generation of steam necessary for the two water-gas shift reactors. In the case of low temperature off streams found in the CO_2 compression unit organic Rankin Cycles can be applied to further improve the system.

In order to lower a power plants' impact on the environment a thorough investigation has to be done into there energy balance to find the best operating option. This paper aims to do so, in the case of a flexible power plant that can also produce hydrogen.