World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:9, No:05, 2015

Monte Carlo Risk Analysis of a Carbon Abatement Technology

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Abstract : Climate change represents one of the single most challenging problems facing the world today. According to the National Oceanic and Administrative Association, Atmospheric temperature rose almost 25% since 1958, Artic sea ice has shrunk 40% since 1959 and global sea levels have risen more than 5.5 cm since 1990. Power plants are the major culprits of GHG emission to the atmosphere. Several technologies have been proposed to reduce the amount of GHG emitted to the atmosphere from power plant, one of which is the less researched Advanced zero emission power plant. The advanced zero emission power plants make use of mixed conductive membrane (MCM) reactor also known as oxygen transfer membrane (OTM) for oxygen transfer. The MCM employs membrane separation process. The membrane separation process was first introduced in 1899 when Walter Hermann Nernst investigated electric current between metals and solutions. He found that when a dense ceramic is heated, current of oxygen molecules move through it. In the bid to curb the amount of GHG emitted to the atmosphere, the membrane separation process was applied to the field of power engineering in the low carbon cycle known as the Advanced zero emission power plant (AZEP cycle). The AZEP cycle was originally invented by Norsk Hydro, Norway and ABB Alstom power (now known as Demag Delaval Industrial turbo machinery AB), Sweden. The AZEP drew a lot of attention because its ability to capture ~100% CO2 and also boasts of about 30-50 % cost reduction compared to other carbon abatement technologies, the penalty in efficiency is also not as much as its counterparts and crowns it with almost zero NOx emissions due to very low nitrogen concentrations in the working fluid. The advanced zero emission power plants differ from a conventional gas turbine in the sense that its combustor is substituted with the mixed conductive membrane (MCM-reactor). The MCM-reactor is made up of the combustor, low temperature heat exchanger LTHX (referred to by some authors as air pre-heater the mixed conductive membrane responsible for oxygen transfer and the high temperature heat exchanger and in some layouts, the bleed gas heat exchanger. Air is taken in by the compressor and compressed to a temperature of about 723 Kelvin and pressure of 2 Mega-Pascals. The membrane area needed for oxygen transfer is reduced by increasing the temperature of 90% of the air using the LTHX; the temperature is also increased to facilitate oxygen transfer through the membrane. The air stream enters the LTHX through the transition duct leading to inlet of the LTHX. The temperature of the air stream is then increased to about 1150 K depending on the design point specification of the plant and the efficiency of the heat exchanging system. The amount of oxygen transported through the membrane is directly proportional to the temperature of air going through the membrane. The AZEP cycle was developed using the Fortran software and economic analysis was conducted using excel and Matlab followed by optimization case study. This paper discusses techno-economic analysis of four possible layouts of the AZEP cycle. The Simple bleed gas heat exchange layout (100 % CO2 capture), Bleed gas heat exchanger layout with flue gas turbine (100 % CO2 capture), Pre-expansion reheating layout (Sequential burning layout) – AZEP 85 % (85 % CO2 capture) and Pre-expansion reheating layout (Sequential burning layout) with flue gas turbine– AZEP 85 % (85 % CO2 capture). This paper discusses Montecarlo risk analysis of four possible layouts of the AZEP cycle.

Keywords : gas turbine, global warming, green house gases, power plants
Conference Title : ICEEA 2015 : International Conference on Environmental Engineering and Applications
Conference Location : London, United Kingdom
Conference Dates : May 25-26, 2015