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Annual Performance of a Solar Reforming Plant Integrated in the Alumina Process

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The solar reforming of methane allows the storage of solar enegy in chemical form. The conversion of natural gas into syntesis gas (syngas), a mixture of hydrogen and carbon monoxide, increases the energy content of the fuel by 20-30%. This technology can offer a smooth transition from fossil-fuel driven industrial processes to full renewable industrial processes reducing the CO_2 emissions. High-temperature thermal processing of minerals (e.g. Alumina production) are suitable processes where this technology can be deployed.

Two highly endothermic reactions can be distinguished in the methane reforming process:

$CH_4 + H_2O \leftrightarrow CO + 3H_2$ (steam methane reforming)

$CH_4 + CO_2 \leftrightarrow 2CO + 2H_2$ (dry methane reforming)

In addition, one exothermic parasitic reaction is produced at the same time:

$CO + H_2O \leftrightarrow CO_2 + H_2$ (water gas shift)

Chemical equilibrium conversion is usually assumed due to the fast kinetics of the reactions. The concentrated solar energy on the aperture of the receiver provides the high-temperature energy source needed to achieves significant fuel conversion at reasonable flow rates.

In this work, we present a new dynamic model of a solar reforming plant for annual simulations. The model is implemented in Modelica language following an object-oriented methodology. The main physical phenomena have been identified and encapsulated into independent and reusable modules which were interconnected graphically to build up the final system. This approach provides a versatile tool to study different plant designs to optimize the annual efficiency. The model was used to study how the variability of the solar resource impacts on the reforming process and how to minimize this impact on the mineral process. Plant designs with storage and without storage are developed and operating strategies implemented to meet with the required 24/7/365 power input in the mineral process. The Figure 1 shows the varying composition of the inlet and outlet power of a the reforming plant without syngas storage. The solar field plant was designed to provide 50 MWth in nominal conditions. The reformer is designed to work at 8 bar and 800 °C and an inlet composition of 2.5 moles of H_2O per mol of CH_4. In this scenario, the CH_4 conversion (in mass) in the reforming process is about the 87.1% and the total annual CH_4 savings is about 3.7%. Other scenarios have been developed for different levels of storage.

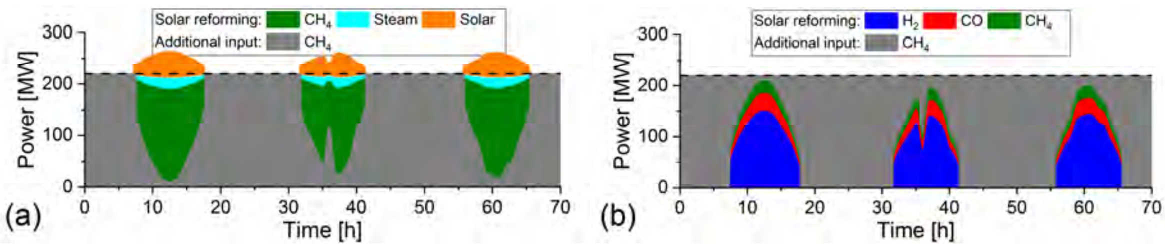

Figure 1: Composition of a) the inlet power and b) outlet power for the solar reforming plant without storage during three days of simulation