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Analysis of CO2 separation with MCFCs operating on simulated exhaust gases from biogas engines

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Objectives: short, medium and long term

University of Seville proposed to support a model of a CHP island (3 reciprocating engines) powered with the biogas produced in the connected wastewater plant treatment. In addition, it has foreseen a mcfc unit as a retrofit to separate partially the carbon dioxide emitted from chp-island, exploiting the function principles of that technology. Various lay-out plant arrangement of MCFC and ICE, fueled by biogas or alternatively with natural gas, are possible, since Spanish regulation allows the use of up to 10% of fossil fuel (i.e. natural gas) to incentive renewable plants. The proposed model required to lead performance and characterization test on a mcfc-type (molten carbonate fuel cell) single cell in different working conditions reproducing the different available scenarios. The experimental campaign executed allows evaluating the mcfc ability to adapt to the proposed scenarios taking into account the main performance parameters of the mcfc as the electrical efficiency, power production, carbon dioxide removal ability and the assessment of the retrofitting plant sizing. The application of a mcfc unit as a carbon dioxide separator, on the long term, leads to the development of CCS (carbon capture and storage) system for a wastewater treatment plant where power and heating are produced with negative carbon dioxide emissions, by collecting the CO2 produced by the biogas exploitation.

Brief summary of work carried out

The Fuel Cell Laboratory specifically assembled and run a single mcfc for three different operative conditions corresponding to the three different lay-out of the system CHP-island (3 reciprocating engines) and mcfc unit: a) 3 ICE fed with biogas and the mcfc fed with NG (10% of the overall available fuel) b) 2 ICE and the mcfc fed with biogas with no NG consumption c) Same of case (b) optimized with 3 different recirculations (cathodic outlet to cathodic inlet, anodic outlet to cathodic inlet and anodic outlet to reformer) utilized totally or partially. In all three cases the cathodic inlet is composed with the ICE exhaust off gases with the important difference that in the case (b) and (c) they are enriched and diluted with air to improve the O2/CO2 ratio according the mcfc needs. The anodic mixture reproduced the natural gas (a) and biogas (b, c) steam reforming, as described in a user previous work. Finally, the fuel cell was characterized with IV curves for the 5 possible scenarios obtained from the three pure proposed lay-out and by hybridizing the (a) and (b) cases (anode (a) fuel with cathode (b) inlet and vice versa) to examine and compare all the interesting cases.

Main achievements intended for publication

The (a) cathodic operative condition showed to limit strongly the mcfc performance, due to the poor oxygen content: the voltage quickly dropped reaching both low electrical and low carbon dioxide removal efficiencies. The natural gas feeding, compared with the biogas feeding, showed higher absolute power production but lower electrical efficiency due to the better capacity of the biogas configuration to exploit the fuel. Since the mcfc feed by NG reached higher current density then it was also able to reach higher carbon dioxide removal factor even if the biogas introduces more CO_2 in the anode so to reach higher value of the carbon dioxide stocked (i.e. present in the anodic off gas) coming from the same CO_2 source (the wastewater plant).

Difficulties encountered

The operative conditions showed to be very stressing for the tested fuel cell so that it did not allow test with constant Uf and U_{co2} (“use of fuel” and “use of carbon dioxide”, respectively) curves for the high values foreseen for these parameters. Alternatively, tests were led by collecting IV curves.

Further comments