COMBINED HEAT AND POWER PROTOTYPE UNIT FOR RESIDENTIAL USE

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The paper deals with a 5 kW Proton Exchange Membrane Fuel Cells Stack Combined Heat and Power prototype system for a residential application, designed to study the mass and energy flows for the optimal strategy to operate it in order to provide efficient, clean, on-site electricity and heat to residential users.

Preliminary testing of the system was carried-out and results are presented.

Keywords: combined heat and power, reformer, fuel cell stack, energy balance

1. Introduction

The need for a cleaner and secure power and for a better environment is the engine driving the use of fuel cell stack - combined heat and power (FCS-CHP) systems for a wide range of generated power, leading to some important benefits: increasing overall system efficiency thanks to the effective use of heat at the point of use; long term cost savings by eliminating energy loss thanks to the distributed generation of heat and power; negligible noise emissions.

CHP systems having less than 15 kW are grouped under the generic name of micro-CHP and are utilised mainly for residential applications. The aforementioned benefits, plus those directly addressed to the ultimate user in terms of a comfortable and healthy home environment, potential utility savings, and a reliable supply of energy, contributed to the growing concern for achieving more efficient and cost- effective micro-CHP systems [1], [2].

Nowadays the battle is for the system components improving simultaneously with lowering the costs, and for the operating strategies optimizing in order to improve the system efficiency.

2. Method

The system, developed at the National Hydrogen & Fuel Cell Center (NHFCC) from the National R&D Institute for Cryogenics and Isotopes

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Technologies ICIT Rm. Valcea, consists mainly of a reformer and a Proton Exchange Membrane Fuel Cells Stack (PEMFC).

The reformer has a compact structure, including two reformate gas purifying units – a carbon monoxide (CO) shift reactor and a selective methanation reactor, and is provided with a flameless oxidation (FLOX) recuperative burner.

He FCS-CHP system includes also the sub-systems of fuel and air supply, water cooling, heat recovery, sensing and controlling, and power conditioning.

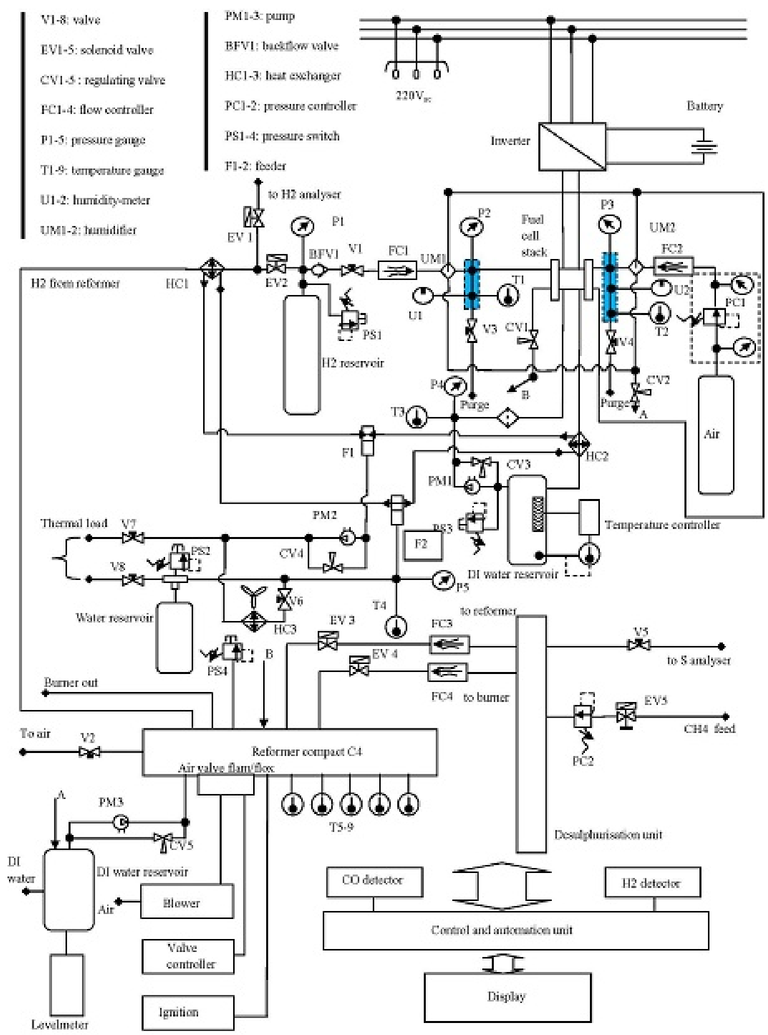

Fig. 1. Schematic diagram of the FCS-CHP system

Fig. 2. Overview of the FCS-CHP system

The fuel cells stack combined heat and power (FCS-CHP) system can deliver 220V ac power and 60^0C hot water. Its schematic diagram is presented in Fig. 1 and its overview is presented in Fig.2.

The reformer uses a steam reforming catalytic process, working on natural gas as fuel. The use of waste water treatment gas, bio gas and syngas as reformer feeding gas is also possible. The removal of the sulphur compounds, as hydrogen sulphide and sulphur dioxide, is required in this case, because they poison the reformer catalyst, so a desulphurizing unit being provided on the feeding line.

The steam is locally generated, using the reformer's burner heating power.

The burner unit consists of an integrated start burner, which works as a classical diffusion burner and is used to heat-up the combustion chamber above the self-ignition temperature of the gas mixture. Then the system switches to the FLOX® (FlameLess OXidation) mode, when a distributed reaction occures in the combustion chamber, where no visible flame is detected, and thus the temperature field is close to a homogenous one. The FLOX temperature for natural gas is around 800^0C. This allows the use of various calorific power mixtures, like methane-hydrogen mixtures in varying proportions, as a fuel. The burner has an integrated recuperative heat exchanger (HE), which uses the heat taken from the flue gas to preheat the combustion air. This HE has a high efficiency, making possible the burner operation at steady air flow, the heat requirement being fulfilled by adjusting the amount of fuel.

The steam reforming is a process through wich any hydrocarbon reacts with steam on a specific catalyst, at high temperature, resulting, theoretically, hydrogen and carbon dioxide. Reactor feeding is made using steam in excess (steam to carbon ratio of 3 to 4). In fact, carbon monoxide, methane and water are also reaction byproducts. In order to remove the carbon monoxide, which is poisonous for the fuel cells electrodes, aditional purifiyng stages are utilised: a shift reactor followed by a selective methanation. After the shift stage, the reformate still contains 1000 ppm of carbon monoxide.

After selective methanation, the reformer is producing 92 lpm reformate gas containing mainly Hydrogen (75%), and also CO_2(22%), CH_4 (<2%), other (<1%, from which CO<1 ppm) from a feeding of 16 lpm methane and 4 lpm de-ionised water.

The feed and the fuel stream are thermally de-coupled. On the reformer side, the reformate gas is cooled by evaporating the process water to produce the steam ; in turn, the steam cools the carbon monoxide removal reactors, reaching the temperature to enter the reformer. On the burner side, the exhaust gas is cooled by pre-heating the combustion air. In fig. 3 the heat management of the reformer is presented.

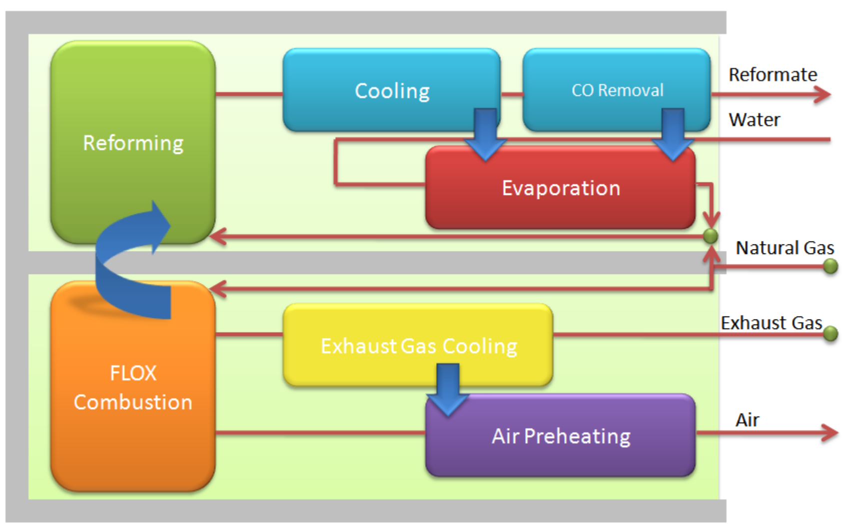

Fig. 3. Heat management of the reformer

The reformate is fed to the anode of a 5 kW PEMFCS, and the energy of the tail gas is recovered via catalytic combustion.

Filtered air is supplied to the cathode of the FCS by means of a blower. 3 kg/hour of water at 65^0C is produced there.

For 4.2 kW generated power, the FCS must be supplied with 21 lpm of hydrogen and 20 lpm of air.

The anode-off gas of the fuel cells is returned to the burner, acting as fuel. During the start-up time of the reformer, till the carbon monoxide in the reformate is reaching the adequate concentration to feed the FCS, the reformate is also used as fuel.

The additional heat from the fuel processor exhaust gas (hydrogen cooling is needed to put its temperature in agreement with the FCS specifications) and those from FCS (heat generated by FCS is recovered by circulating cooling water through the stack), extracted via heat exchangers, is delivered to an external hot water tank.

The power conditioner converts and inverts the electricity generated by the FCS. A part of 650W of the generated power is used for the system itself functioning, and the difference is delivered to the load.

The computer controlling system is realized with NI CompactFieldPoint modules and is based on LabView software platform. Sub - routines control the fuel-processor, the FCS and the CHP assembly. More measuring points than those required for the controlling of the normal operation are included, in order to provide data for future optimization. Print screen of the home page of the controlling software is presented in Fig.4.

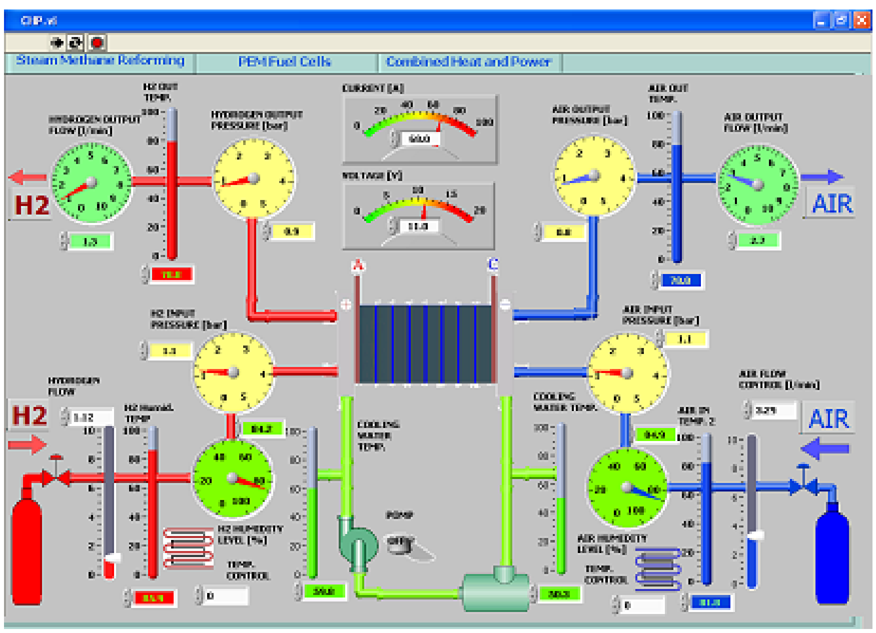

Fig. 4. The home page of the CHP prototype controlling software

3. Results

The FCS-CHP system was commissioned and functioned uninterrupted 6 weeks, producing 4032 kWh electric power and 12096 kWh thermal power, from which 7560 kWh is produced by the FCS.

4. Conclusions

Future work is needed for increasing the system efficiency by a better heat recovery and the improvement of the controlling system.

R E F E R E N C E S

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