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Characterisation of a 3 kW PEFC power system coupled with a metal hydride H_2 storage☆

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Abstract

Fuel cells and hydrogen storages, eventually integrated in hybrid power systems with hydrogen production from renewables, represent an interesting option for small stationary applications such as power generation in remote sites beyond the grid or back up power for telecom stations.

This paper deals with the CESI RICERCA experiences on a polymer electrolyte fuel cell (PEFC) power system fuelled with the hydrogen supplied by a metal hydride storage. The power system consists of three ReliOn Independence 1000 PEFC units, a battery bank and a 3.3 kWe DC–AC converter (inverter). The hydrogen storage is made of $LaNi_5$ type powders and can supply more than 6 Nm^3 of hydrogen per discharge cycle. The PEFC units, the inverter and the hydrogen storage performances were characterised. These subsystems were integrated into an automated power generation system and connected to a local grid including other power generators, power quality analysers, energy storage systems and electrical loads.

The main features of the integrated system are analysed herein. In particular the overall system stability upon cycling, the heat transfer issues and the possibility of recovering the fuel cell waste heat to extract hydrogen from the metal hydrides are discussed. Finally, during grid-connected operations, the power quality indexes were measured and found in agreement with the EN 50160 standard.

Keywords: PEFC; Metal hydrides; Hydrogen; Distributed power generation

1. Introduction

Hydrogen represents an important option to store energy in a long-term scenario of fluctuating power generation from renewable sources (solar and wind). Independently of the primary energy sources used for hydrogen production (fossil fuel with carbon dioxide sequestration, nuclear, renewable), R&D efforts must be focused henceforward on hydrogen related technologies, such as fuel cells and advanced storage systems.

Fuel cells represent the ideal system to efficiently and cleanly convert the hydrogen chemical energy into electricity. Low temperature polymer electrolyte fuel cell (PEFC) could be an interesting option for small (<10 kW) stationary applications in remote sites, integrated in hybrid systems with photovoltaic (PV) panels and batteries and/or coupled with hydrogen generation from renewables [1–4]. The back up power systems for base transceiver stations of telecom operators [5–7] represent another interesting application for PEFC units. As a matter of fact the costs of traditional lead acid battery back up power plants is rather high, due to periodic battery replacement, maintenance costs and disposal fees and telecom operators are looking for alternative technologies. Some manufacturers are currently developing PEFC units with a few kWe output for this market [8] and small series productions are already available.

Field tests of grid connected and stand alone small stationary PEFC units are in progress. Among them different hybrid systems are under testing that combine fuel cell units with renewable sources (wind or solar) and electric storage systems to power remote site customers [5,6,9]. Modelling activities are focusing the optimisation of the component size and the operating strategies of hybrid systems including fuel cells, batteries, photovoltaic panels, small wind turbines, electrolysers for hydrogen production directly from renewables, etc. [10–13].

Nevertheless several features of these innovative power systems are worth to be systematically investigated. Hydrogen

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storage based on metal hydrides have to face a number of charge and discharge cycles without loosing their storage capability. Waste heat from fuel cells should be used to extract the hydrogen from the metal hydrides and heat transfer is a critical issue in full-scale devices. Performances and reliability of the available PEFC units have to be assessed. Finally the electric power system behaviours in stand alone and grid connected configurations have to be investigated with a view both to the end user and to the electric network. The capability of following typical end user load profiles and of satisfying the power quality standards has to be verified.

This paper deals with the CESI RICERCA experimental activities on a PEFC power system fuelled with hydrogen stored in metal hydrides and connected to a low voltage grid with distributed generators, power quality, energy storage systems and several kinds of electrical loads. Results of the single component characterisations as well as of the integrated system behaviour are reported and discussed.

2. Experimental

The integrated system realised at CESI RICERCA and schematically represented in Fig. 1 is described herein.

The 6.5 Nm^3 capacity hydrogen storage was set up by using commercial intermetallic powders (LabTech Int. Ltd., Sofia, Bulgaria). The intermetallic is of the $LaNi_5$ type, with nickel partially substituted by aluminium ($LaNi_{4.65}Al_{0.35}$).

The PEFC power system consists of three 1 kWe PEFC units, a battery bank and a 3.3 kWe DC–AC converter (inverter). All these items were supplied by SGS future Srl (Cavalese TN, Italy). The PEFC units are ReliOn Independence 1000 with a 48 V DC regulated output. The Independence 1000 units are based on the proprietary “Hot-Swappable Modular Cartridge Technology™” and include six cartridges of 10 cells each. The battery bank consists of two groups of four 12 V/79 Ah sealed Pb type batteries. The DC–AC converter was realised following CESI RICERCA specifications. It is a 400 V AC, three-phase inverter based on three single-phase Sunny Boy 1100LV units with a maximum rated efficiency of 92%.

The behaviour of each of the three PEFC units connected to the battery bank was investigated both in steady state conditions, with gradually increasing load, and during steep load changes. A water-cooled electronic load (TDI Dynaload, model WCL 488) was used for this tests.

The hydrogen flow rate into each PEFC unit was measured by means of a 20 Nl min^{-1} full-scale mass flow meter (MKS Instruments GmbH). The meter was previously calibrated by means of a MKS Califlow type A200, Serial Number 95081001N (reference conditions $T = 0\,°C$ and $p = 760$ mmHg). The uncertainty was certified to be below the 0.7% of the full scale in the whole operating range between 2 and 20 Nl min^{-1}. The flow data were measured every 2 s, corrected by means of the flow meter calibration curve and averaged over a period of at least half an hour. A drum was inserted in the hydrogen line between the PEFC unit and the flow meter in order to mitigate the disturbances due to the periodic purges of the dead end anodic compartment of the PEFC.

The hydrogen flow during the metal hydride storage charging was measured and regulated by means of two 200 Nl min^{-1} full-scale mass flow controllers (MKS Instruments GmbH). A maximum flow rate was fixed that limits the first minutes of charging phase, whereas most of the charge occurs at lower flow rates up to a complete saturation.

In all the experiments described in this paper 99.999% pure hydrogen from pressurised cylinder packs was used. The carbon

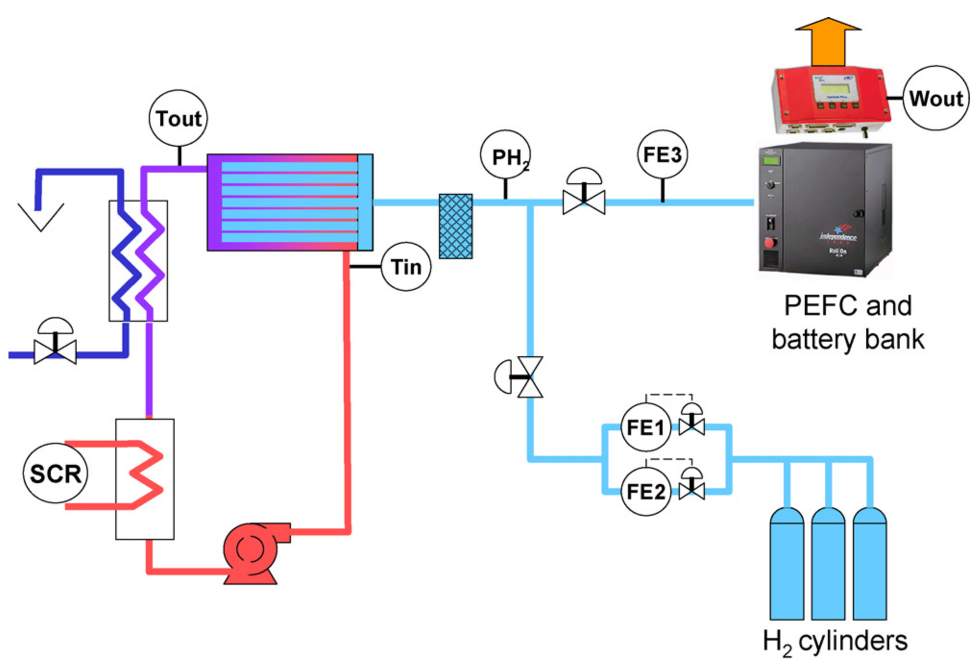

Fig. 1. Scheme of the integrated systems (FE1, 2—hydrogen mass flow controller; FE3—hydrogen flow meter; PH_2—pressure gauge; Tin, out—PT100 temperature gauges; SCR—thyristor unit; Wout—electric power output meter).