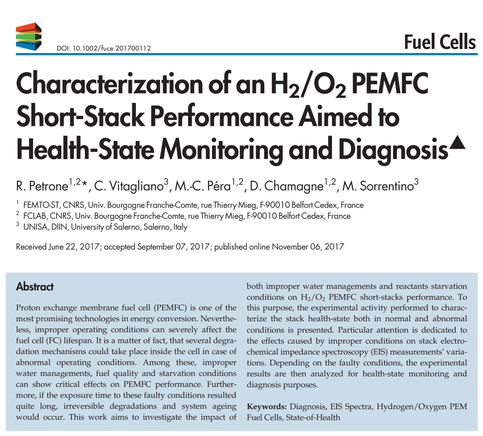
Real operation pem fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis

DISSEMINATION

Papers (3 Published - 2 Under Submission)



Fuel Cells

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Characterization of an H_2/O_2 PEMFC Short-Stack Performance Aimed to Health-State Monitoring and Diagnosis▲

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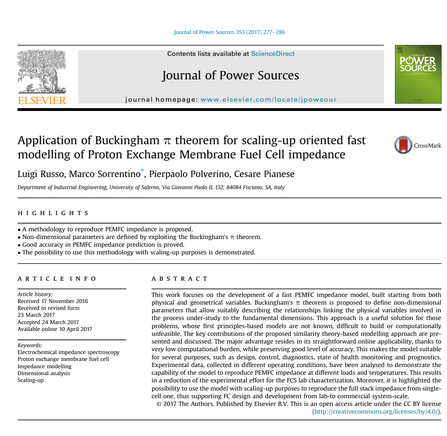
Abstract

Proton exchange membrane fuel cell (PEMFC) is one of the most promising technologies in energy conversion. Nevertheless, improper operating conditions can severely affect the fuel cell (FC) lifespan. It is a matter of fact, that several degradation mechanisms could take place inside the cell in case of abnormal operating conditions. Among these, improper water managements, fuel quality and starvation conditions can show critical effects on PEMFC performance. Furthermore, if the exposure time to these faulty conditions resulted quite long, irreversible degradations and system ageing would occur. This work aims to investigate the impact of both improper water managements and reactants starvation conditions on H_2/O_2 PEMFC short-stacks performance. To this purpose, the experimental activity performed to characterize the stack health-state both in normal and abnormal conditions is presented. Particular attention is dedicated to the effects caused by improper conditions on stack electrochemical impedance spectroscopy (EIS) measurements' variations. Depending on the faulty conditions, the experimental results are then analyzed for health-state monitoring and diagnosis purposes.

Keywords: Diagnosis, EIS Spectra, Hydrogen/Oxygen PEM Fuel Cells, State-of-Health

ORIGINAL RESEARCH PAPER



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Application of Buckingham π theorem for scaling-up oriented fast modelling of Proton Exchange Membrane Fuel Cell impedance

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HIGHLIGHTS

- A methodology to reproduce PEMFC impedance is proposed.
- Non-dimensional parameters are defined by exploiting the Buckingham's π theorem.
- Good accuracy in PEMFC impedance prediction is proved.
- The possibility to use this methodology with scaling-up purposes is demonstrated.

ARTICLE INFO

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Electrochemical impedance spectroscopy
Proton exchange membrane fuel cell
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Dimensional analysis
Scaling-up

ABSTRACT

This work focuses on the development of a fast PEMFC impedance model, built starting from both physical and geometrical variables. Buckingham's π theorem is proposed to define non-dimensional parameters that allow suitably describing the relationships linking the physical variables involved in the process under-study to the fundamental dimensions. This approach is a useful solution for those problems, whose first principles-based models are not known, difficult to build or computationally unfeasible. The key contributions of the proposed similarity theory-based modelling approach are presented and discussed. The major advantage resides in its straightforward online applicability, thanks to very low computational burden, while preserving good level of accuracy. This makes the model suitable for several purposes, such as design, control, diagnostics, state of health monitoring and prognostics. Experimental data, collected in different operating conditions, have been analysed to demonstrate the capability of the model to reproduce PEMFC impedance at different loads and temperatures. This results in a reduction of the experimental effort for the FCS lab characterization. Moreover, it is highlighted the possibility to use the model with scaling-up purposes to reproduce the full stack impedance from single-cell one, thus supporting FC design and development from lab-to-commercial system-scale.

- Generalized scaling-up approach based on Buckingham theorem for Polymer Electrolyte Membrane Fuel Cells impedance simulation. Polverino, P.; Bove, G.; Sorrentino, M. ICAE2018, published on Energy Procedia – Selected for Applied Energy Special Issue submission.
- Under submission: 2 journal papers dealing with the state of the art of diagnostics techniques and PEMFC faults, respectively.

Conferences and events

- 6th Int. European PEFC & Electrolyser Forum 2017
- Electrochemical Science and Technology Conference and Annual Meeting of The Danish Electrochemical Society 2017
- IEEE, Vehicle Power and Propulsion Conference, 2017
- Fundamentals & Development of Fuel Cells, 2017
- 7th EFC "Piero Lunghi" Conference, 2017
- FCH2JU Review Days 2016 – 2017 – 2018

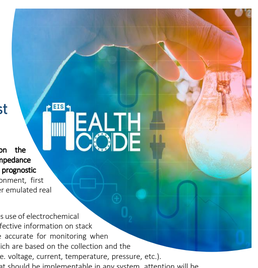
Public Deliverables*

- D5.1 System Testing Procedure
- D5.3 Diagnostic Tool Final Validation
- D6.1 Project Website
- D6.6 Workshop N.1
- D6.7 Final Demonstration Workshop N.2

*available on project website + public abstract

Students involvement

- 2 PhD students
- 1 master + 6 bachelor students



- Public Abstract -

Deliverable D2.1

Technical specifications and test procedure

The HEALTH-CODE project focuses on the development of an Electrochemical Impedance Spectroscopy (EIS)-based diagnostic and prognostic tool to be validated in laboratory environment, first under controlled conditions and then under emulated real operation.

The main technique proposed, which makes use of electrochemical impedance spectroscopy (EIS), provides effective information on stack electrochemistry. These results are more accurate for monitoring when compared to conventional techniques, which are based on the collection and the processing of several indirect measures (i.e. voltage, current, temperature, pressure, etc.). With the objective of developing a tool that should be implementable in any system, attention will be given to the problem of making it as general as possible, which in turn entails its easy and cheap customization. **It is worth remarking that future straightforward implementations are also envisaged for APU, mobile and automotive systems, and other electrochemical devices (batteries, electrolysers) which may embed the tool for monitoring and diagnosis.**

HEALTH-CODE will face the challenge of delivering a monitoring and diagnostic tool able to evaluate the current state of health of a Proton Exchange Membrane Fuel Cells (PEM FCS) and to detect faults as well as forthcoming failures. The application will focus on stationary PEM FCS for μ-CHP (1 kW) and backup (3 kW) applications, equipped with different stacks and running under real operating conditions.

The project deals with 5 major faults:
- Water management (drying, flooding)
- Fuel quality change (contaminants)
- Sulfur poisoning
- Fuel Starvation
- Oxidant starvation.

Dedicated diagnostics algorithm will be developed on the basis of the acquired EIS data and test results will support the development and tuning of the Hardware dedicated to the final device.
This document aims at creating a Test Protocol for PEMFC stacks (UPS and μCHP use) in order to create valuable data for training diagnosis algorithm to be embedded on a final real-time diagnostic tool dedicated to the previously mentioned technologies.
In order to assure reproducibility and laboratory interoperability, this test protocol has been based on the exploitation of previous FCH JTI projects dealing with PEM stack testing characterization and EU standardisation (ref 1-5) and it has been adapted to H-CODE project purposes through the exploitation of partners' expertise (ref 6).

WORKSHOPS & COMMUNICATION

Joint workshop HEALTH-CODE-DIAMOND

Luzern (July 2017) - 6th International European PEFC & Electrolyser Forum.

- 45+ Participants
- 16 presentations (1 speech from industry + 1 special contribution)
- 100+ Flyers distributed

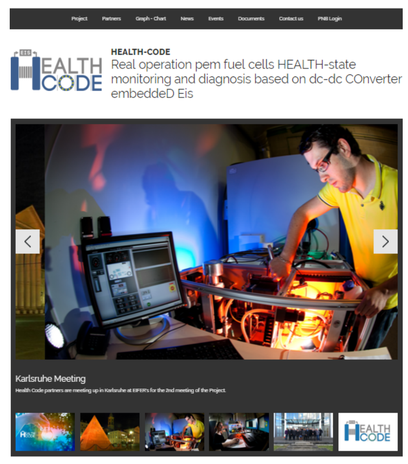
Joint workshop HEALTH-CODE-INSIGHT

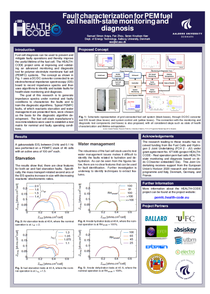
Brussels (November 2018) – PRD2018

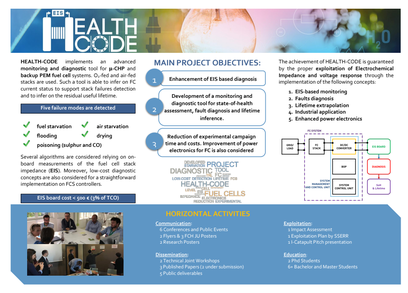
- 60+ Participants
- 12 presentations (3 speeches from industry)
- Future exploitation focus

Communication materials

- 2 flyers & 3 FCH JU posters
- 3 posters
- 1 video (on-board EIS diagnosis) on the website







EXPLOITATION

I-CATAPULT 2018*

* EIFER innovation challenge

Capture innovations at an early stage and develop new ideas in a bottom-up process for the four strategic axis:

- Smart and Sustainable City
- Local Multi-Energy Systems
- Low Carbon Hydrogen Solutions (HEALTH-CODE)
- Energy Transition, Markets and Environment
- Cross-cutting topic of Data Science

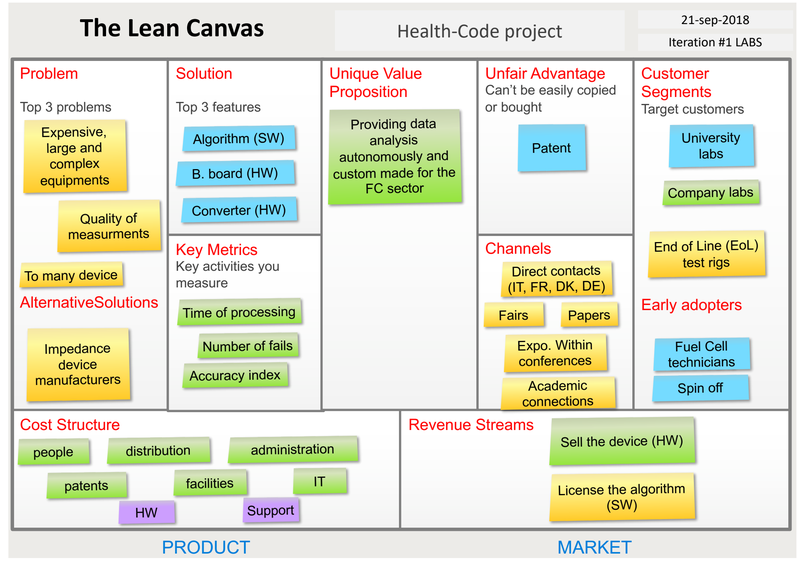
SSERR

"How to turn concept into Business"

Support Services for Exploitation of Research Results

Two potential industrial follow-up

Inputs for Business Plan



IMPACT ASSESSMENT

An internal workshop on impact assessment was held during the 4th project meeting in Belfort (February, 2017). It was chaired by Absiskey who organized the workshop into three sessions.

Aim: to collect "genuine" ideas on how the project will impact at personal, laboratory/team and organization levels. During the session the partners provided their vision on how this RIA project would impact after its closure.

www.pemfc.health-code.eu

The project HEALTH-CODE (Real operation pem fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis) has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 671486. This Joint Undertaking receives support from the European Unions' Horizon 2020 research & innovation programme and N.ERGHY.