INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2015) 1–16

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Failure Mode and Effect Analysis, and Fault Tree Analysis of Polymer Electrolyte Membrane Fuel Cells

*Michael Whiteley**, *Sarah Dunnett*, *Lisa Jackson*

Aeronautical & Automotive Engineering Department, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK

ARTICLE INFO

Article history:
Received 27 July 2015
Received in revised form
26 October 2015
Accepted 1 November 2015
Available online xxx

Keywords:
PEMFC
Reliability
Fuel cell
Fault Tree

ABSTRACT

Hydrogen fuel cells have the potential to dramatically reduce emissions from the energy sector, particularly when integrated into an automotive application. However there are three main hurdles to the commercialisation of this promising technology; one of which is reliability. Current standards require an automotive fuel cell to last around 5000 h of operation (equivalent to around 150,000 miles), which has proven difficult to achieve to date. This hurdle can be overcome through in-depth reliability analysis including techniques such as Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) amongst others. Research has found that the reliability field regarding hydrogen fuel cells is still in its infancy, and needs development, if the current standards are to be achieved. In this work, a detailed reliability study of a Polymer Electrolyte Membrane Fuel Cell (PEMFC) is undertaken. The results of which are a qualitative and quantitative analysis of a PEMFC. The FMEA and FTA are the most up to date assessments of failure in fuel cells made using a comprehensive literature review and expert opinion.

Copyright © 2015, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.

Introduction

With the increase in environmental awareness and climate change concerns in recent years, hydrogen fuel cells have been put forward as a technology that could potentially reduce greenhouse gas emissions. Anthropogenic activities contribute to climate change mainly through Greenhouse Gas (GHG) emissions from fossil fuel based energy sources. These harmful GHGs are comprised of, among others, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that contribute to the greenhouse effect. Additionally, energy prices are set to continue to rise by alarming rates [1] which will disrupt the energy system of many countries due to a rise in oil prices. Therefore an alternative energy source would mitigate energy security and pricing concerns to a certain degree.

The United Kingdom (UK) emitted 549.3 Million tones of Carbon Dioxide equivalent ($MtCO_2e$) in 2011 [2] and 122.2 $MtCO_2e$ was due to the transport industry, with 74% of this figure due to cars, taxis and buses [3]. Due to the aforementioned negative environmental impacts of emissions from fossil fuel energy sources, this figure needs to be dramatically reduced not only to meet government targets, but for the health of the biosphere. The UK government set out targets to

* *Corresponding author*. Tel.: +44 (0)7896 009 227; fax: +44 (0)1509 227 275.
E-mail address: m.whiteley@lboro.ac.uk (M. Whiteley).

http://dx.doi.org/10.1016/j.ijhydene.2015.11.007

0360-3199/Copyright © 2015, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Whiteley M, et al., Failure Mode and Effect Analysis, and Fault Tree Analysis of Polymer Electrolyte Membrane Fuel Cells, International Journal of Hydrogen Energy (2015), http://dx.doi.org/10.1016/j.ijhydene.2015.11.007

reduce GHG emissions in the ‘Climate Change Act’ of 2008. The act presents the targets of an 80% reduction of greenhouse gas levels by 2050, with a closer target of a 34% reduction by 2020. These two targets are based upon the level of GHG emissions in 1990 [4]. The targets are legally bound and therefore must be met, thus many initiatives and research has emerged to aid the UK in reaching these targets. Other countries have also pledged to tackle climate change, with the US president stating that the US will reduce CO_2 emissions 17% from 2005 levels by 2020, 42% by 2030 and finally 83% by 2050.

Hydrogen fuel cells have the potential to mitigate the aforementioned climate change concerns, as they are a zero-emission energy conversion device. They use H_2 and O_2 to form water, releasing heat and electrical energy. Their only emissions are water, meaning that at the point of use, the fuel cell has no carbon emissions associated with it. If the H_2 fuel is sourced from renewable means, the whole process is zero emissions and therefore has the potential to dramatically cut CO_2 emissions in a number of industries.

Fuel cells currently suffer from reliability concerns, and are more likely to contribute to the above issues if the current reliability issues are overcome.

Hence, this paper analyses the reliability of a PEMFC using in-depth techniques in order to understand how their performance can be improved. The layout of the paper is as follows:

In Section Reliability analysis, the reasons for studying PEMFCs is given, followed by a brief description of the techniques used in reliability analysis. Section Reliability analysis describes the reliability techniques adopted here and previous related studies on the reliability of PEMFCs. Section Proposed FMEA describes the FMEA performed and the main conclusions drawn from it. Section Proposed FT outlines the Fault Tree (FT) developed and Section Conclusions concludes the findings of the study.

Reliability analysis

The US Department of Energy (DoE), Japanese New Energy and Industrial Technology Development Organisation (NEDO) and European Hydrogen and Fuel Cell Technology Platform (HFP) Implementation Panel (IP) have all set reliability targets for PEMFCs in automotive application of a lifetime of more than 5000 h of operation (equivalent to around 150,000 miles operation) [5]. The current state of fuel cell development struggles to meet these targets, and as such, an in-depth reliability analysis of PEMFCs is invaluable to help manufacturers and developers. Such an analysis requires obtaining a detailed understanding of the failure modes of all the different parts of the cell, and the effects the failures have on the cell as a whole.

Currently, the understanding of the reliability of PEMFCs is still in its infancy, and requires further development to help with the commercialisation of this promising technology.

The work presented in this paper uses the techniques of FMEA and FTA to comprehensively ascertain key failure phenomena and analyse their role and effects within in an automotive PEMFC system. Boundaries are set to only consider the PEMFC itself, the balance of plant and supporting ancillaries are omitted as shown in Fig. 1, where the functional block diagram of a simple fuel cell automotive system is shown. The dotted rectangle shows the boundaries of the system considered here.

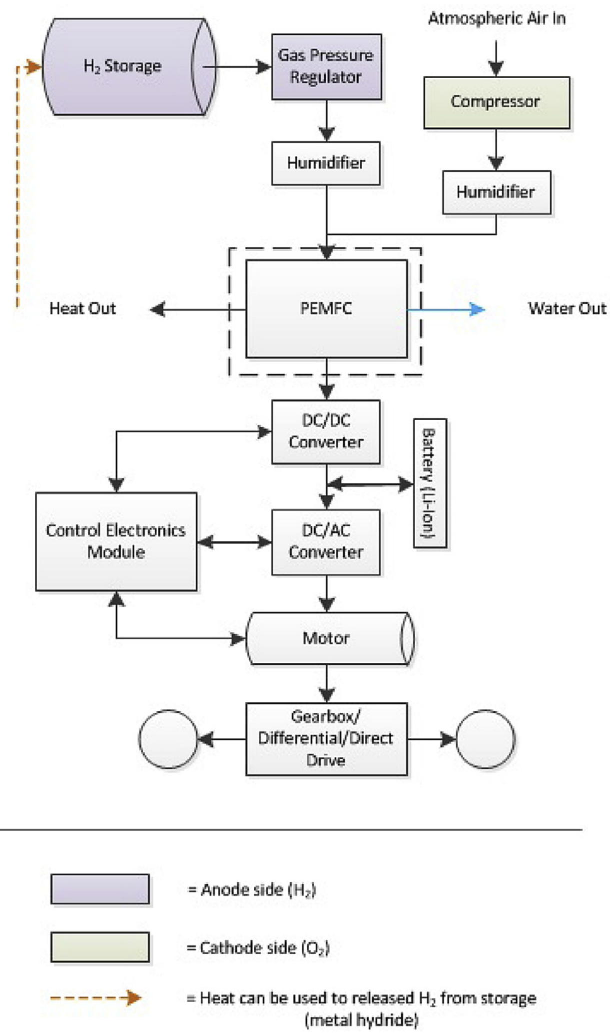

Fig. 1 – Boundaries of presented reliability analysis.

PEM FMEA

FMEA is a bottom-up approach to analysing equipment, or a system, with relation to its failure events. That is to say that the analysis of the system starts with the individual components that make up the system, rather than looking at the overall system and working top-down. The technique is a systematic scrutiny of all of the individual ways in which a component or piece of equipment can fail, and the effect of that failure on the overall system's operation. Any additional features can be added to a basic FMEA such as mitigation strategies and poignant remarks for the reader. It is ideally used early on in the development cycle in order to ascertain key failure modes that can be designed out as early as possible. It should not, however, be limited to the design stage

Please cite this article in press as: Whiteley M, et al., Failure Mode and Effect Analysis, and Fault Tree Analysis of Polymer Electrolyte Membrane Fuel Cells, International Journal of Hydrogen Energy (2015), http://dx.doi.org/10.1016/j.ijhydene.2015.11.007

Download English Version:

https://daneshyari.com/en/article/7712855

Download Persian Version:

https://daneshyari.com/article/7712855

Daneshyari.com