Examining the variable versus stable modes operation of Power-to-Gas (P2G) for an energy storage

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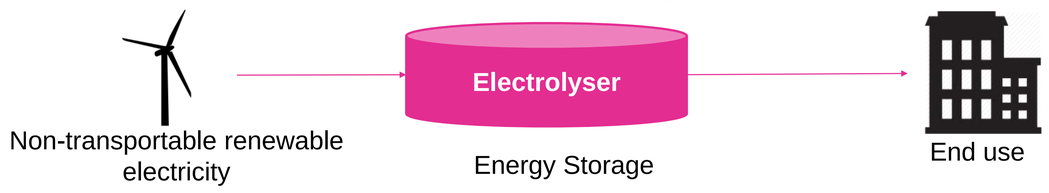
Energy Systems Integration Partnership Programme

Introduction

Decarbonisation of the gas grid has been in the agenda for combatting climate change for a long time now. The addition of more renewable gas vectors in the energy system would mean, competing with existing cheaper fossil fuels. This study examines the ability of using an electrolyser for storing large amounts of intermittent renewable electricity in the form of hydrogen by examining the effects of temperature and other parameters on the flow rate of hydrogen.

Objectives

1. Identify the parameters of the electrolyser that has the most impact on its performance.
2. Examine the impact of these parameters on the electrolyser during variable operation on the flow rate of hydrogen.



Methodology

Step 1- Calculate the over potential in the cell[1]

$$E_{cell} = E_{nernst} + E_{act,cathode} + E_{act,anode} + E_{ohm} \quad (1)$$

Step 2- Calculate the temperature transients based on the response time of the electrolyser[1,2]

$$C_p\left(\frac{dT}{dt}\right) = (E_{cell} - V_{tn})I - h(T - T_{ambient}) \quad (2)$$

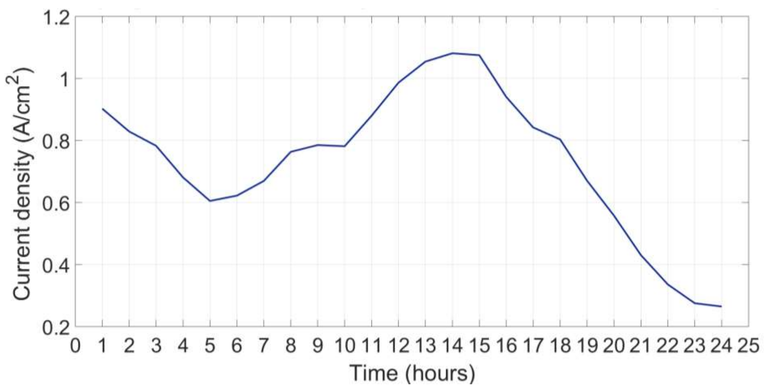
Step 3- Calculate the flow rate of the hydrogen from the electrolyser[3]

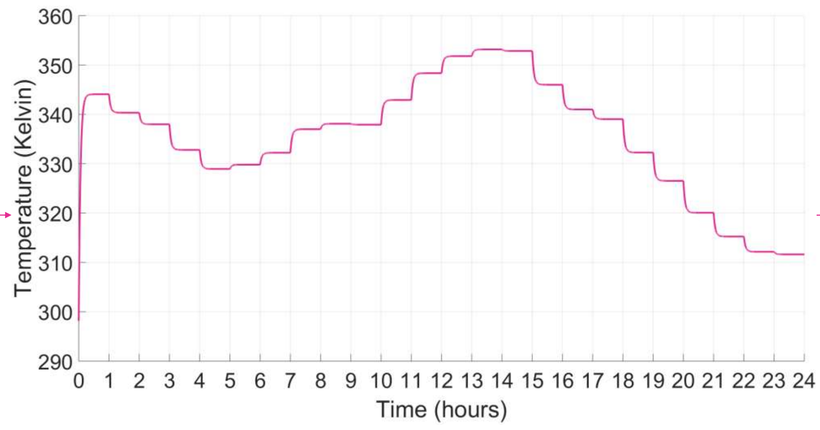
$$\eta_{H_2} = \eta_{faraday} * \frac{I}{2*F}, \eta_{faraday} = \frac{\left(\frac{I}{A}\right)^2}{f_1 + \left(\frac{I}{A}\right)^2} * f_2 \quad (3)$$

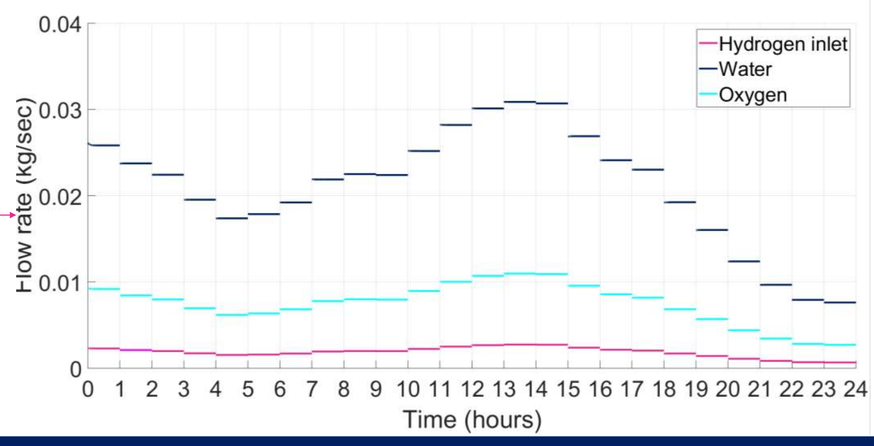
Where $f_1 and\ f_2$ are temperature dependant

Definition of parameters

Parameters	Definition
$E_{cell}, E_{nernst}, E_{ohm}$	Total, Nernst and Ohmic voltages , *Volts*
$E_{act,cathode}, E_{act,anode},$	Anodic and cathodic overpotentials, *Volts*
V_{tn}	Thermoneutral cell voltage, *Volts (typically 1.48 V)*
h	Heat transfer co-efficient of the cell, *Watts/Kelvin*
C_p	Specific heat capacity of the cell, *Joules/Kelvin*
I	Current, *Amperes*
T	Temperature inside the electrolyser, *Kelvin*
T_a	Ambient temperature, *Kelvin*
Λ (lambda)	Water content in the membrane, *(ranges between 9 (dry membrane) 15-20 (Wet membrane)*
η_{H_2}	Flow rate of hydrogen, *Moles/second*
$\eta_{Faraday}$	Faradays efficiency, *%*
A	Area of the cell, *Centimetre²*
F	Faradays constant, *96485 Coulombs*

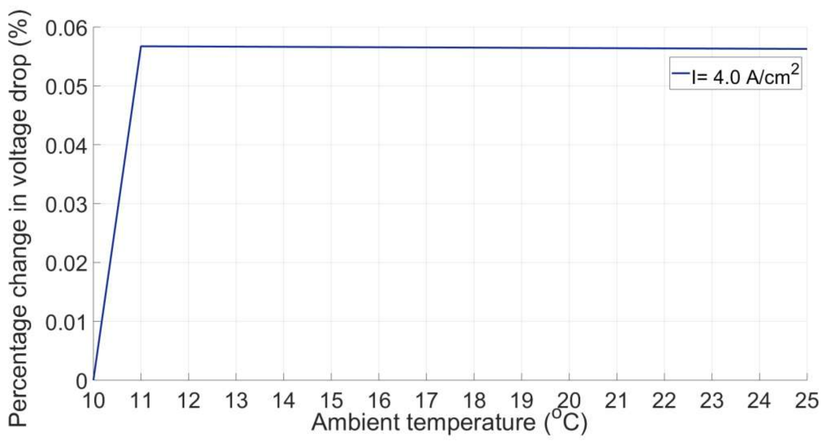


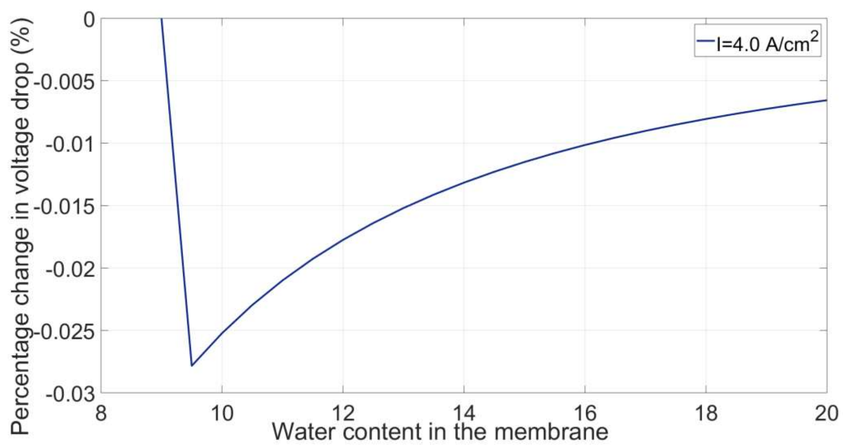




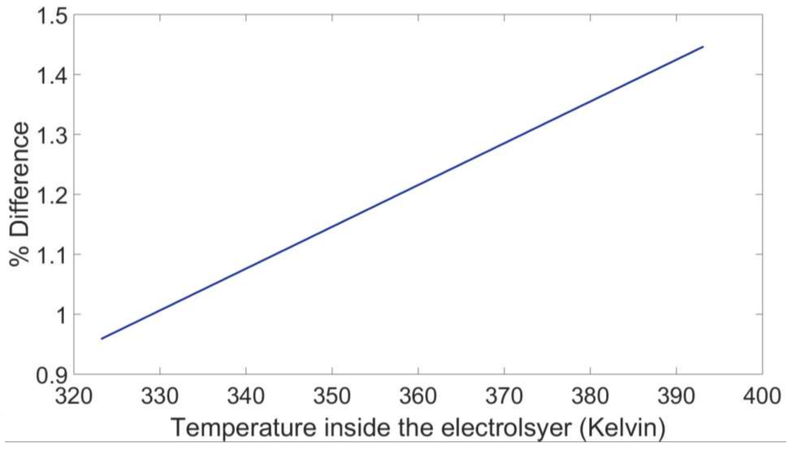
Results

1. Effect of Ambient temperature and the water content of the membrane on the percentage change in voltage drop in the electrolyser





2. Effect of temperature inside the electrolyser flow rate of hydrogen



$$Difference = Flow\ rate_{H_2}(I) - Flow\ rate_{H_2}(I,T)$$

Conclusions and discussion

1. The temperature changes in the electrolyser have the most significant impact on the flow rate of hydrogen, when compared to other parameters such as the ambient temperature of the room and the water content of the membrane.
2. More research into the material of construction in the electrolyser could aid in significantly improving performance of an electrolyser.
3. Due to the high variation in cost and performance between different types of electrolysers[4], economic factors could significantly influence the nature of operation of the electrolyser.

References

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Acknowledgement

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under the SFI Strategic Partnership Programme Grant Number SFI/15/SPP/E3125. The opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Science Foundation Ireland.