Characterisation of a Proton Exchange Membrane Electrolyser by Electrochemical Techniques

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***Abstract*—Electrolysers can be used in renewable energy systems to produce hydrogen with the hydrogen acting as an energy carrier. This paper presents the characterisation of a proton exchange membrane (PEM) using electrochemical techniques. The characterisation will yield information about the different components of the PEM electrolyser. An equivalent electrolyser model will be used to accurately represent the current and voltage terminal characteristics as well as the energy transfer from electrical to hydrogen.**

***Index Terms*—Characterisation, electrochemical techniques, hydrogen production, PEM electrolyser**

I. Introduction

Hydrogen can be used as an energy carrier in renewable energy systems. Hydrogen is not naturally available in large quantities and therefore has to be produced. An electrolyser is a device that has the ability to dissociate water into hydrogen and a fuel cell has the ability to convert hydrogen to produce electrical power. When an energy surplus exists in a hybrid renewable energy system (HRES), hydrogen is produced and stored. When an energy shortage occurs, a fuel cell is used to convert the hydrogen into electrical power.

This study focuses on PEM electrolysers as part of the platinum group metal (PGM) beneficiation drive of the department of science and technology (DST). A need exists to better understand PEM electrolysers in order to design and build more efficient systems. The need will be addressed by characterising a PEM electrolyser. Characterisation of a PEM electrolyser is important since specific parameters affect the operating principle of the electrolyser. These parameters include water pressure and -temperature, membrane electrode assembly (MEA) temperature, water concentration and gas (hydrogen and oxygen) concentration.

An electrolyser cell is more efficient at higher temperatures, ranging between 60 and 80 degrees Celsius [1]. Therefore the temperature of the water must be controlled to be the same as the membrane temperature in order to maintain the operating efficiency of the PEM electrolyser [1].

A number of electrochemical characterising techniques are available. The polarisation curve (PC) technique is a standard technique for characterising the performance parameters of an electrolyser cell. It yields information about the electrolyser voltage and current characteristics under different operating conditions [2]. The current interruption (CI) technique can be used to measure the internal (membrane) resistance of the electrolyser [2].

The electrochemical impedance spectroscopy (EIS) technique can be used to yield the following electrolyser characteristics: polarisation loss, diffusion loss, ohmic resistance, charge transfer resistance and the double layer capacitance [2].

The rest of the paper is organised as follows: section II describes the proposed research, section III describes the technique that will be implemented and is section IV a conclusion is given.

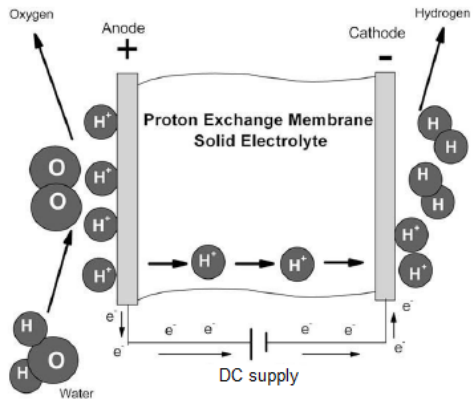

Fig. 1. PEM electrolyser [3]

II. Proposed Research

The aim of the project is to electrochemically characterise a PEM electrolyser and derive an equivalent model of the of the PEM electrolyser. The PEM electrolyser consists of a anode, membrane and a cathode. A depiction of a PEM electrolyser is given in Fig 1. The equivalent model will be used to yield information about the performance characteristics and efficiency of the electrolyser. The electrochemical techniques that will be used for characterisation are the following: the PC technique, the CI technique and the EIS technique.

III. Methodology

The following section provides a methodology that will be used to perform the characterisation of the PEM electrolyser. The first step will be to derive an analytical model of the PEM electrolyser, secondly a simulation model will be developed and lastly the electrochemical techniques will be applied.

A. Analytical model

An analytical model of the electrolyser will be derived from existing literature [4]. The analytical model will be developed using mathematical equations for the power input, water input, electrolyser MEA, electrolyser temperature, electrolyser pressure, hydrogen and oxygen -output.

B. Simulation model

A simulation model of the electrolyser will be developed in a software package like MATLAB® or LabVIEW^{TM}. The simulation model will be based on the analytical model.

C. Electrolyser experimental setup

A typical electrolyser experimental setup is given in Fig 2. The experiments will be carried out by applying the electrochemical techniques described above. The experimental setup consists of a PEM electrolyser, a temperature controlled water tank, a combined power supply and electrochemical interface, an oscilloscope, a computer and measuring devices to measure the produced hydrogen and oxygen volumes. The oscilloscope will be used for the PC and CI techniques. The electrochemical interface, consisting of a potentiostat and a frequency response analyser (FRA), will be used for the EIS measurements.

The first experiment will be performed by applying the PC technique. This will be achieved by operating the electrolyser for a period of time and recording the voltage vs. current values. These results will form the basis of the steady state operating characteristics.

The CI technique will be applied next. The electrolyser is operated at a constant current value and the voltage vs. time values are recorded. When the current supply is interrupted, it causes a voltage transient in the electrolyser. The membrane resistance is calculated by dividing the voltage change by the constant current value recorded before the interruption. The CI technique is very limited giving only information about the membrane resistance.

Lastly, the EIS technique will be performed by applying a small alternating current (AC) excitation signal (voltage or current of known amplitude and frequency) to the electrolyser cell. When a AC voltage signal is applied the resulting AC current signal is measured and vice versa. This technique uses very small excitation amplitudes, often in the range of 5 to 10 mV, and will be applied over a frequency range of 0.1 to 100 kHz.

The impedance signal is determined by dividing the voltage signal by the current signal. Bode plots will be used to plot the amplitude- and phase values of the impedance signal. Nyquist plots will be used to plot the real- and imaginary part of the impedance signal. An equivalent electrical circuit, called a Randles cell, will be used to interpret EIS data and determine the double layer capacitance, the membrane resistance and the charge transfer resistance.

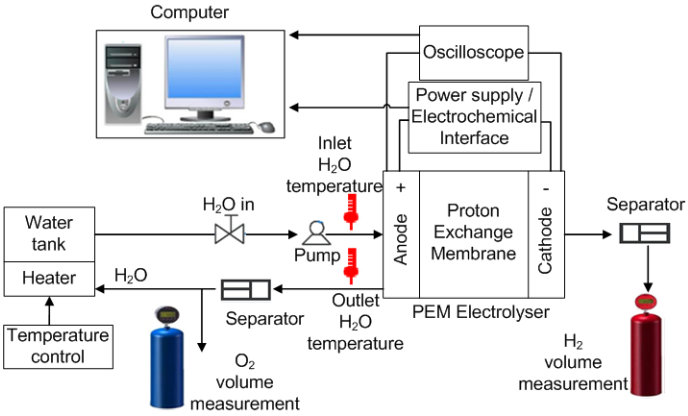

Fig. 2. PEM electrolyser experimental setup

IV. Conclusion

Characterisation of a PEM electrolyser will be performed. The characteristics will be determined by applying different electrochemical techniques. The simulation model can be used to simulate a PEM electrolyser setup. The simulation results can be used to yield a representation of how the electrolyser will react to specific parameter changes. Experimental results will be compared with simulation results to identify any differences. The membrane resistance values obtained from the CI and EIS techniques will be compared to identify any correlations or differences.

V. Acknowledgement

This project resides in the HySA Infrastructure competency centre, part of the Department of Science and Technology Hydrogen Programme.

References

[1] mer Faruk Selamet, F. Becerikli, M. D. Mat, and Y. Kaplan, "Development and testing of a highly efficient proton exchange membrane (PEM) electrolyzer stack," *International Journal of Hydrogen Energy*, vol. In Press, Corrected Proof, pp. –, 2011.

[2] J. Wu, X. Z. Yuan, H. Wang, M. Blanco, J. J. Martin, and J. Zhang, "Diagnostic tools in PEM fuel cell research: Part I Electrochemical techniques," *International Journal of Hydrogen Energy*, vol. 33, no. 6, pp. 1735 – 1746, 2008.

[3] L. Ma, S. Sui, and Y. Zhai, "Investigations on high performance proton exchange membrane water electrolyzer," *International Journal of Hydrogen Energy*, vol. 34, no. 2, pp. 678 – 684, 2009.

[4] F. Marangio, M. Santarelli, and M. Cali, "Theorectical model and experimental analysis of high pressure PEM water electrolyser for hydrogen production," *International Journal of Hydrogen Energy*, vol. 34, pp. 1143–1158, 2009.

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