Chapter 1

Introduction

In this chapter an overview of renewable energy systems and the applicability of characterising electrolysers are discussed. Subsequently, the problem statement regarding the research problem is discussed. After that, the issues to be addressed regarding the current interrupt method are discussed. Lastly, the research methodology is discussed.

1.1 Background

The global working industry is highly dependent on some form of energy and currently the main supply comes from non-renewable energy sources like fossil fuels [6]. The availability of fossil fuels worldwide are steadily declining, but will remain the major supply of energy for at least the next 20 years [6]. Energy can also be harvested from renewable energy sources like wind and solar [7]. However, the energy supply from renewables are intermittent and on its own cannot meet the energy demand.

Over the last couple of years research has focused on generating electrical power efficiently from renewable energy [7]. A hybrid renewable energy system (HRES), consisting of more than one renewable energy source in combination with a non-renewable energy source, can be implemented. An example of a HRES is depicted in Figure 1.1. The HRES consist of the following, wind turbines, solar panels and hydro turbines as energy inputs. In the HRES there exists an Alternating Current (AC) and a Direct Current (DC) load. DC is harvested from the solar panels, where AC is harvested from the wind turbines and hydro turbines. The DC is used to power a electrolyser and charge batteries. An electrolyser is an electrochemical device which produces hydrogen. The hydrogen is used in a fuel cell to produce DC.

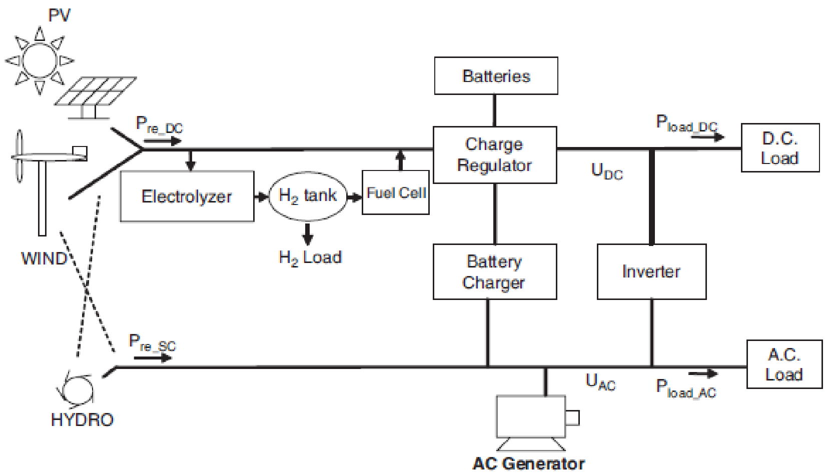

Figure 1.1: Renewable energy hybrid system [1]

The batteries and hydrogen are used for energy storage. Energy is harvested from the batteries and hydrogen, and fed to the DC load. AC is generated from the hydro plant and wind turbines. Backup AC power is supplied from a AC generator (usually a diesel generator). AC power can also be harvested from the DC bus by using a inverter to convert the DC to AC.

Hydrogen is therefore used as an energy carrier in HRESs. Excess electrical energy from the HRES can be stored in the form of hydrogen. A PEM electrolyser is an electrochemical device capable of generating pure hydrogen from water. When a DC voltage is applied to the PEM electrolyser, water is split into hydrogen protons, electrons and oxygen gas.

A PEM electrolyser consists of various complex components and their interfaces require advanced diagnostic methods for a better fundamental understanding. Various characterisation methods exist like the Polarisation Curve (PC) method which can be used to benchmark an electrolyser and indicate the different loss regions within the electrolyser [8]. Electrochemical Impedance Spectroscopy (EIS) is used to indicate the impedance of a PEM electrolyser at various frequencies. The impedance is usually represented by an equivalent electric circuit (EEC) model and depicted on a Nyquist plot or a Bode plot [8].

Another characterisation method is the Current Interrupt (CI) method. The CI method is normally used for estimation of the ohmic losses within an electrochemical system. The CI method has been implemented on other electrochemical cells like batteries and fuel cells.

1.2 Problem statement

Characterisation tools are required to indicate the relationship between the performance and functional properties of the PEM electrolyser components. The purpose of this study is to characterise the various components of a PEM electrolyser. These components include the PEM, the catalyst layer, the diffusion media and the flow fields.

A PEM electrolyser will be characterised by implementing an electrochemical characterising method namely the CI method. In this study, the CI method is used to indicate the electrochemical characteristics of the PEM electrolyser.

1.3 Issues to be addressed

1.3.1 Current interrupt method

The CI method, consisting of the natural voltage response (NVR) method and the current switching (CS) method, will be used to develop two EEC models of the PEM electrolyser. The CI method is an electrical test, where the current and voltage waveforms are used to obtain the two EEC models of the PEM electrolyser. Information is extracted from the EECs which relate to the electrochemical characteristics of the PEM electrolyser, namely the ohmic losses, the activation losses and the concentration losses.

1.3.2 Current interrupt simulation

Simulation models for both EEC models are developed and simulated. The NVR method and the CS method is applied in simulation. The simulation models are used to verify and validate the NVR method and the CI methods. The NVR and CS methods are practically implemented after validation.

1.3.3 Current interrupt implementation

A practical implementation of the CI method is developed for a PEM electrolyser. Real models of the EECs, consisting of the Randles cell and the Randles-Warburg cell, is developed for the PEM electrolyser. The estimated parameter values of the EECs is used as a diagnostic method to indicate electrochemical loss regions of the PEM electrolyser.

1.4 Research methodology

1.4.1 Current interrupt method

A flow diagram, depicted in Figure 1.2, provides an overview of the steps taken during the evolution of the CI method. Firstly a literature study regarding the research problem is conducted. After sufficient information is gathered, the CI method is developed to estimate the parameters of the EEC. Thereafter, a simulation model is developed and tested. After the CI method is verified and the results validated in simulation, the method can be implemented practically.

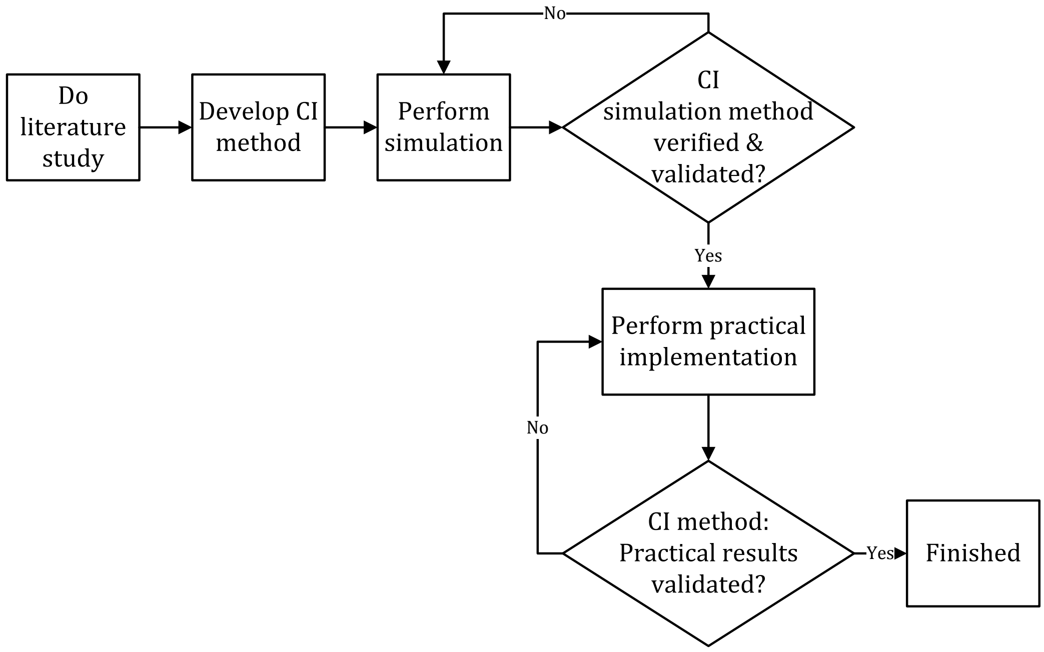

Figure 1.2: Flow diagram: CI method development

1.4.2 Current interrupt simulation

A simulation model of the CI method is developed and tested before it is practically implemented. A simulation model consisting of the two EECs is developed. Applicable EEC parameter values are selected and applied. The simulation is performed and the necessary data is recorded. The data is analysed and the EEC parameter values are estimated. Then, the CI method is verified and lastly the results are validated.

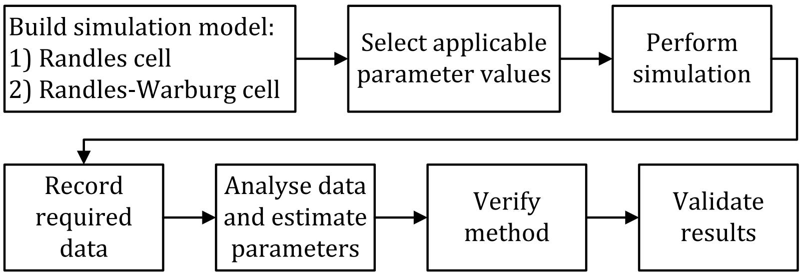

Figure 1.3: Flow diagram: Development of simulation model for CI method

1.4.3 Current interrupt implementation

Once the CI method is verified in simulation, it can be implemented experimentally. Firstly, the PEM electrolyser experimental setup is constructed. Then, the NVR and CS methods are applied and the necessary data is recorded. Thereafter, the data is analysed and the parameter values of the EECs are calculated. Lastly, the calculated parameter values are validated.

Figure 1.4: Flow diagram: Implementation of CI method

1.5 Dissertation overview

The rest of the document is organised as follow, presented in chapter 2 is a literature study which addresses all the necessary literature regarding the research problem. In chapter 3 the NVR method and the CS method, regarding the estimation of the EEC parameters, are discussed. In chapter 4 the simulation models and results are discussed. The practical implementation of the CI method is presented in chapter 5. Lastly, conclusions and recommendations are discussed in chapter 6.