Chapter 1

INTRODUCTION

This chapter presents an overview of the research and development done on the creation of software package which can perform design optimisation tasks and costing analyses for a Renewable Energy Hydrogen System (REHS).

1.1 BACKGROUND

A project was proposed to the North-West University by the South African Department of Science and Technology (DST) to develop a system responsible for the production of hydrogen gas in remote and civil areas through the use of renewable energy sources. These sources are to provide a system using electrolyser technology of given complexity, with the energy required to perform the hydrogen production process, creating a self-sufficient production facility.

The main benefit of such a system lies in the remote nature thereof. Due to the low population per unit area in South Africa [1], the transmission of energy and supply of product to decentralised communities is very expensive. This is mainly due to the large distances that need to be covered by supply lines from singular production facilities in order to provide the public and various industries with required products and services.

The development of remote hydrogen production facilities will ease the distribution of gas to its various users (prospective clients for hydrogen supply) and may prove to be a more cost-effective solution versus the general methods of transport, as surrounding communities or other companies will be able to produce the gas and supply the users with their hydrogen requirements. Another potential benefit is that the supplying of hydrogen gas to nearby industries by communities or towns in the vicinity will generate a sustainable income for the local populace, creating jobs and lowering production costs of hydrogen consuming industries.

It is envisioned that when prospective clients plan to invest in the development and construction of an REHS-based plant they be presented with a software package which, based on a specified location's natural energy resources, can model such a plant in terms of energy source allocation, required plant component types and component configurations. The development of a software package which conforms to these requirements is the main objective at which the aforementioned project is aimed at.

1.2 SOFTWARE REQUIREMENTS

The software package is centralised around the development of two distinct software models. The first is a Technical Simulation Model (TSM), developed by M.G. De Klerk [2], which uses demographical and meteorological information to perform technology selections for renewable energy projects based on the abundance of natural renewable sources. The second refers to an Economic Simulation Model (ESM) which can use either the outputs of the TSM, or manual user inputs to perform design optimisations of prospective REHS-based plants in terms of cost-effective plant configurations. A Power Allocation Table (PAT) should be defined in the application environment, which will enable the ESM to compare various plant configurations in terms of ratio's between solar and wind power source usage.

This project is concerned with the creation of an ESM based on a predetermined hardware model. It must take all general factors influencing cost and efficiency into consideration and must present the client with a detailed model analysis in terms of projected costs, component configuration and recommendations. Supplying the client with estimated efficiency numbers will also be advantageous for comparative reasons. The functionality is to be incorporated into an application developed in the LabVIEW environment, which is ideal for real-time simulation applications.

1.3   RESEARCH OVERVIEW

As stated, the main purpose of this project lies with creation of a software package prescribing to a specified set of requirements. In order to ensure the proper application of the required research, we must take a software engineering approach for the development of the application.   Therefore we begin the research overview by discussing a software development methodology in which we can integrate the research process to best benefit the critical success factors of the program.   Using this methodology as framework, we can continue to elaborate on the research focus-areas which are important for the development of procedures that satisfy the required functionality of the ESM.

1.3.1 Software development methodology

In any design-type project, a set of prescribed rules or steps are usually provided which should be followed by the design team in order to get the job done efficiently. This case is just as applicable when it comes to the development of a software product. Here, one can theoretically break the process down into a series of predetermined steps [3] as depicted in *Figure 1.1*.

In the ideal case, the client brings a problem to a development team who converts the problem into a new idea or concept that is to be developed "from scratch". Once the idea has been envisioned, the specific requirement-sets or artifacts of the software product are determined by the development team. When the requirement-artifacts have been finalised, they are analysed and individualised, where each can be approached by a specified group. This follows into the design phase where the individual analysis-artifacts are used to produce a design. The implementation of all designs into the final software product may be achieved hereafter, followed by post delivery services, including availability of system upgrades, and further software support or maintenance.
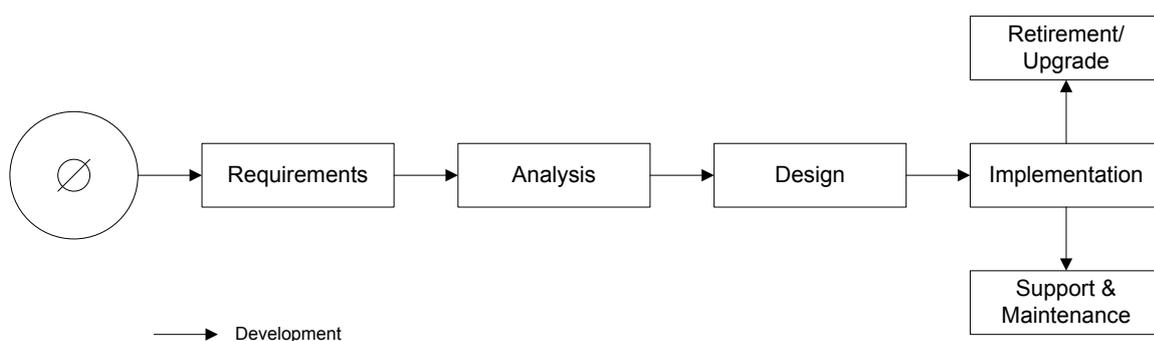

Figure 1.1 – Idealised software development procedure [3]

However, as pointed out in [3], the development of software in practice is considerably different than following a strictly theoretical procedure. Two factors are attributed to this: one is that software professionals are human, and therefore error is usually introduced in the specified processes; the other is that the client for which the software product is being developed may change their requirements during the developmental phase of the project. Amako [4] specifically relates to this when discussing the software model development for high energy physics experiments for the Large Hadron Collider (LHC). Here it is discussed that software methods are not so widely appreciated in speciality software creation, as a pragmatic approach is necessary to allow for creative intervention during developmental phases.

The scope for the software development of the ESM however, is not nearly as large as that of the LHC related projects. Irrespective of this, the nature of the ESM requires that many fields of knowledge be brought into the development of the software product, and since the development team is limited to one person, an incremental approach is essential for the successful integration of all these knowledge areas. Trammel, Pleszkoch and Linger [5] discusses an incremental development model which is a prime example of a type of software life-cycle which may be used for the development of the ESM.
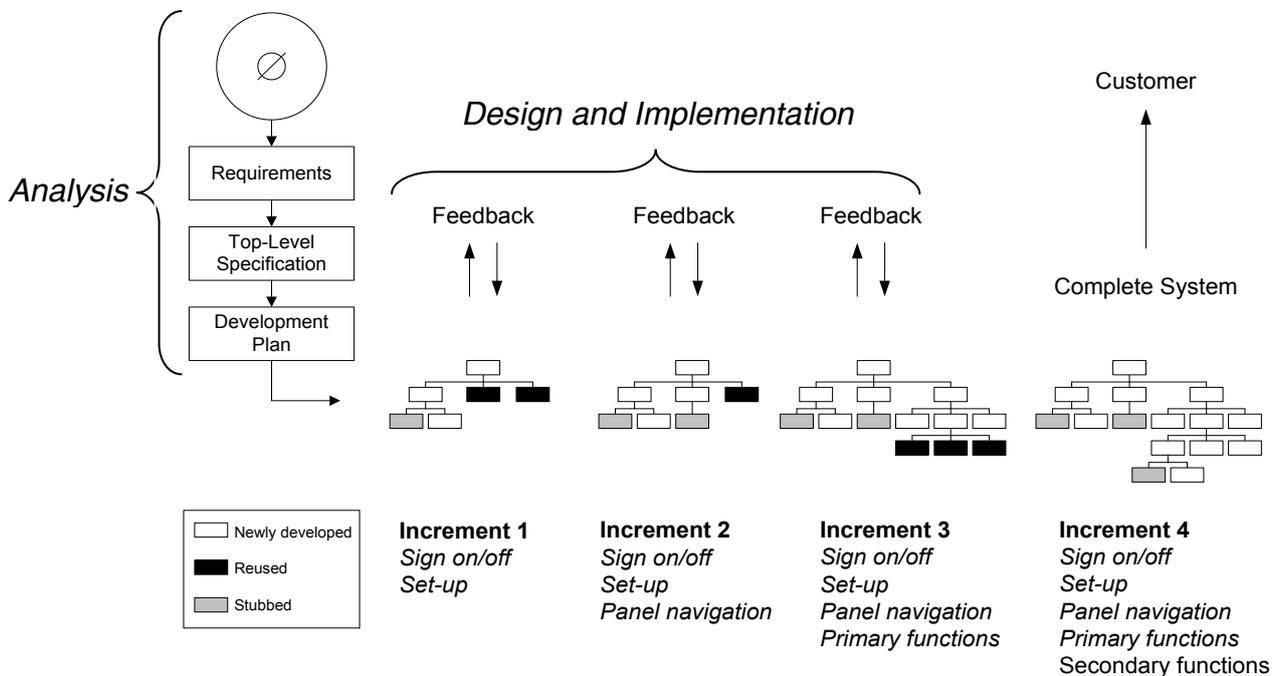

Figure 1.2 – Example of an incremental development life-cycle model [5]

The life-cycle model, as illustrated in *Figure 1.2*, shows how the phases of development are integrated in terms of successive increments of development. Each increment provides a working piece of software, with increasing depth and complexity as the development process proceeds. The scope of research is contained within the analysis, design and implementation workflows of this development cycle. We now continue to elaborate on the context of the research required by the ESM's constituents.

1.3.2 Research context

To properly contextualise the scope of research, we first look at the high-level system definition of the REHS in *Figure 1.3*.
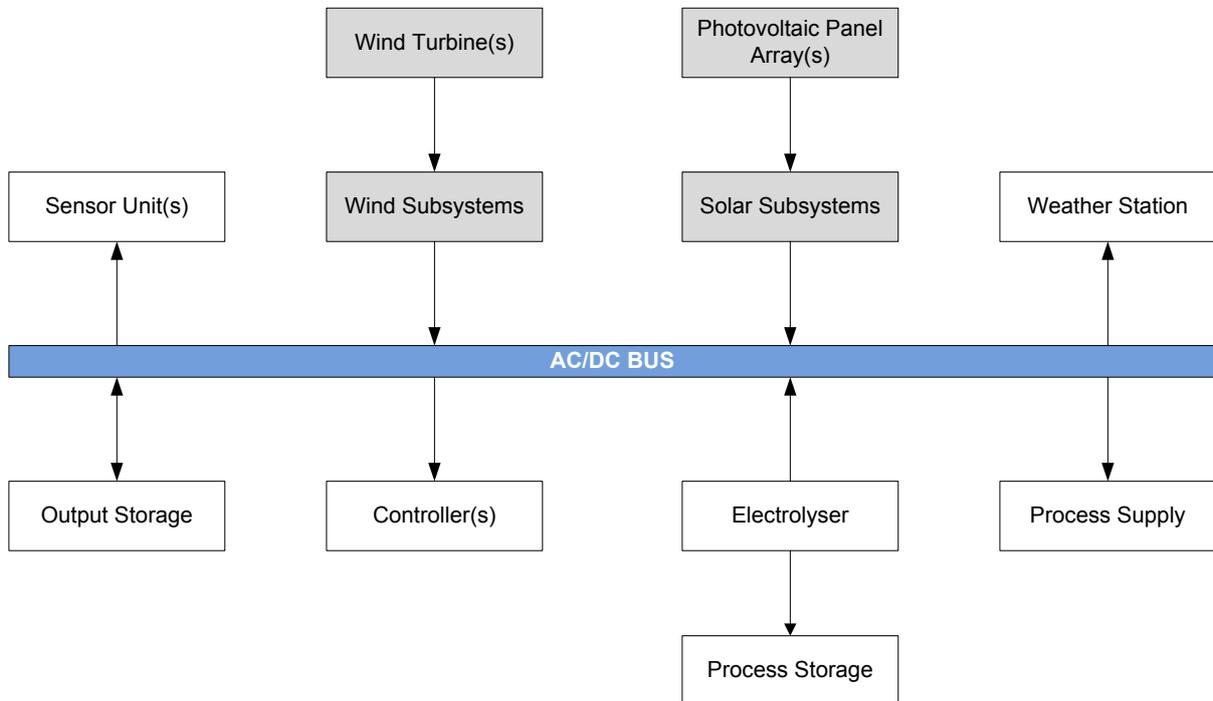

Figure 1.3 – REHS System definition

This definition explains how the different constituents of the REHS interact. Power is transferred via a common AC/DC bus, the choice of which depends on the design specification. The specific constituents that are elaborated on in this dissertation are highlighted in grey.

This system overview also gives a clear indication of the context within which the research is to be placed. The following aspects are important when we consider the required functionality of the ESM and therefore also research application:

- Solar generation technology. The ESM must be able to create permutations of viable photovoltaic arrays using all models of photovoltaic modules listed in a database. This requires in-depth knowledge into the connection profiles of this technology, as well as a look at how these systems can be integrated into larger projects;

- Wind generation technology. Although wind may be a less prevalent renewable energy source for small-scale projects, it may still be required for a viable REHS solution as determined by the TSM, the ESM, or by user preference;

- Auxiliary equipment description. As defined by the REHS design in *Figure 1.3*, additional equipment types should be incorporated into the plant specification for the accurate representation of the effective costs of a system based on the REHS-type design. This includes a weather station for monitoring and data-capturing purposes; battery bank for output storage when renewables are not available for power generation; and process related components, specifically referring to the electrolyser and controller hardware. The ESM must provide options where the number of units for these subsections can be specified.

- Optimisation techniques. The manual specification of each possible model would be extremely time-consuming when the database of available components becomes larger. Therefore the implementation of mathematical optimisation techniques is of critical importance to create a smooth user-experience, while still producing reliable results.

1.3.3 Research outcomes

The main outcomes that stem from the research performed include:

- The development of mathematical models and algorithms which can be used in a software package to create energy-source models for use in plant configuration procedures;

- The successful implementation of optimisation techniques which can cycle through all viable model configurations and choose a model which presents the required characteristics, whilst adhering to specific cost constraints;

- Produce a software model which can incorporate a large amount of components into practically viable plant configurations for an REHS-based plant.

1.4   ORGANISATION

The development of a software package is discussed in this dissertation. The methodology followed is closely linked to the chosen software life-cycle model. In the introductory chapter, we discussed the origins of the project and how the problem presented has been solved. The procedure is outlined and the research context is clearly provided.

In *Chapter 2* a detailed literature study is presented providing the necessary knowledge base for successful integration of technical procedures used by the ESM.

This is followed by *Chapter 3* which outlines the design concept of the software model wich shows where literature-based techniques are implemented as well as providing an oversight into the planned functioning of the ESM.

Chapter 4 proceeds with the development of the ESM based on the concept as depicted in *Chapter 3*, and shows how the algorithms for system sizing and component configuration were developed and how they were practically implemented in the LabVIEW environment.

The testing and verification done on the ESM results are discussed in *Chapter 5*, where the performance of the application is scrutinised, and the results are verified.

Finally, the conclusion provides a summary of all work that was done during the different phases of the development of the ESM, and provides a critical evaluation of the applicability of the ESM in the field.