Chapter 6

CONCLUSION

This chapter provides the reader with a review on the work that was done in this dissertation, a summary of the approach taken for application development and how the research performed was integrated in the application. It also serves to provide concluding remarks on the problems experienced during developmental phases, and discusses key achievements attained. Finally, it closes with comments on the functionality and accuracy of the application and discusses the future prospects of the project.

6.1 SUMMARY OF WORK

The research that was performed for this dissertation was aimed at creating design optimisation techniques in terms of component selection and costing. These techniques had to be implemented into a functional application developed in the LabVIEW environment.

The approach taken started off with a detailed study of the renewable energy fields related to wind power and solar power. A good understanding of the system characteristics had to be achieved in order to create the required design and sizing procedures.

In addition to this, the concept of a hybrid system for hydrogen production was investigated and its different proponents researched, with the main focus alluding to renewable energy integration into such a system. As one could speculate, due to the vast amount of components commercially available, a technique had to be developed that could minimise the time taken for the determination of an optimal solution from a database of a large amounts of components. To this end, optimisation techniques based on heuristic and meta-heuristic theory has been researched.

With the required information used as guideline, the preliminary design of a potentially viable software package was presented in *Chapter 3*. We determined the required functional units using a theoretical software engineering life-cycle which allows for the systematic creation of modules, developed in conjunction with each other. This procedure ensured that the resulting modules were compatible with each other, and that they can all be seamlessly implemented into a single package.

In *Chapter 4* we continued to develop the individual constituents of the modules as pre-defined in *Chapter 3*. This started off with the development of sizing algorithms for the renewable energy sources based on wind and solar technologies, both applicable to an REHS-based system.

The basic integration of modules for all the other, non-variable equipment required for the REHS-based plants were discussed thereafter. Finally, we chose to develop an optimisation algorithm based on the genetic algorithm, due to the fact that it allows for the efficient creation of random, viable permutations of components without having to analyse every single component. Many difficulties had to overcome for the development of this model, and while the functionality has not been perfected, it does work.

Chapter 5 continues with the systematic verification and preliminary validation of the techniques derived in *Chapter 4*. We started off with the verification of results from the base sizing algorithms used by the ESM. This is important, since all results generated by the optimal sizing procedure are only as accurate as the results achieved by these base modules. We verified the implemented techniques with the algorithms theoretically developed. Since these theoretical algorithms were created using numerous viable sources as baselines, the results from these procedures are deemed accurate. The final optimisation results were presented in a summarised format, with the complete output document attached to Appendix A.

6.2 RESEARCH OUTCOMES

The research outcomes around which the work is centred, all relates to the creation of an economic simulation model which has the functionality to:

1. Determine configurations of REHS-based plants, depending on renewable energy sources for power generation, process components, general functional components, and an electrolyser array producing a specified amount of hydrogen.

2. Determine the optimal solution in terms of costs and output the results to the user in a professional manner. This optimal solution must represent the most cost-effective solution considering the plant requirements.

6.2.1 Solar and wind energy integration

PV module and wind turbine technical parameters and system sizing characteristics were investigated. This knowledge was applied in the development of algorithms which are able to size PV arrays and wind turbine arrays based on voltage and power parameters and constraints. The algorithms were designed so that the energy sources were matched to suitably sized inverters or converters, depending on which topology the user prefers.

A case study was defined which was used to test the ESM results-validity and accuracy. Various comparisons were made using different versions of characteristic component parameters. This was achieved by integrating select modules by De Klerk [2] which allow the sizing of component configurations on a much more accurate basis.

6.2.2 System configuration optimisation

The requirement that the ESM must be able to output an optimised solution to the client in terms of the total plant costs was challenging to meet. A technique based on a genetic algorithm was developed for specific application to the REHS design. Simulation results based on the introduction of a case study into the ESM showed that the technique, in its current form, provides a good approximation of the exact solution.

In combination with this, it also reduced the computation speed requirements of the ESM by 47% for this case study. This value will change dependant on the size of the system that is to be sized. It is expected that the larger the system specification becomes, the more prominent the advantage of the GA-bases technique will become.

6.3 INTEGRATION RESULTS

The secondary requirements of the ESM was related to the integration of the TSM, developed by De Klerk [2]. Various modules from the TSM were integrated into the interfaces of the ESM to provide the user with a more interactive experience when using the ESM. The results generated by the TSM are directly used by the ESM. It was found that, after comparing the results of the ESM when using generic input parameters versus TSM input parameters, the accuracy of a sized system increased drastically.

Since the TSM uses meteorological information to determine probable renewable energy system power outputs based on the abundance of energy resources, it enables the ESM to create a much more realistic plant configuration, which can guarantee power supply to a system.

6.4 FUTURE WORK

6.4.1 Module expansion

Many prospective features of ESM could not be implemented due to the time constraints of the project. The most important feature that has been omitted is the development and integration of a battery bank sizing module. This module is very important for overall plant sizing, and must be included in any future work on the project.

Further general modules which may add to the completeness of the ESM should be added, including but not limited to, wiring modules with proper sizing procedures; and process-related modules which can augment the electrolyser sizing procedures

Due to the modular nature of LabVIEW, the integration of new modules into the existing ESM project is relatively simple as long as existing code is understood thoroughly beforehand.

6.4.2 Verification

The verification of the ESM outputs against results of commercially available software would greatly add to the credibility of the ESM solutions. While we mentioned on application that can be used for the partial verification of solar systems, there are other proprietary software packages and freeware available (see *section 5.2)* that produce more complete systems analyses.

6.5 IN SUMMARY

The main research goals that were initially defined were achieved irrespective of the design and implementation challenges faced. The use of the LabVIEW environment for the ESM's development brings a new range of functionality to the user, with real-time interface interaction proving to be most refreshing. With the creation of the ESM, and the consequent integration with the TSM, hybrid renewable energy systems can be easily and accurately sized. Even though this version of the ESM is specifically developed for hydrogen application, it can also be used for other similar projects, and may even be improved to such an extent that it can serve as a sizing platform to many other project types.