SOLVING REAL-LIFE PLANT AUTOMATION APPLICATIONS IN ELECTRICAL ENGINEERING CAPSTONE PROJECTS

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Abstract - The University of South Africa (UNISA) is a comprehensive university offering both academic and vocational qualifications. Tuition is delivered by means of open and distance learning. The School of Engineering is in the process of recurriculating existing Engineering courses to meet the requirements of the new Higher Education Qualifications Framework (HEQF) as well as standards set by the Engineering Council of South Africa (ECSA). Academic outcomes of the Technician and Technologist qualifications, UNISA's mission and vision, strategic plan and tuition model as well as the demands of Industry also need to be considered. To meet all the criteria will require innovative curriculum design, especially with regards to capstone projects. This paper will address the introduction of real-life plant automation projects and provision of suitable training, guidance and assessment rubrics to enable UNISA students to meet required outcomes and graduate attributes.

Keywords - Capstone Projects, Electrical Engineering, Open and Distance Learning and Process Instruments

I. INTRODUCTION

The rapid evolution of technology and developments in Industry has been driving business operations throughout the world and has resulted in changes in Electrical Engineering professions. These changes have necessitated the Department of Electrical Engineering at the University of South Africa (UNISA) to recurriculate existing Engineering courses to meet the requirements of the new Higher Education Qualifications Framework [1] as well as standards set by the Engineering Council of South Africa [2]. The newly developed programme needs to be implemented in 2020. It comprises both a theoretical and practical component. Furthermore, Industry requirements, UNISA's [3] mission and vision, strategic plan and the tuition model all have to be taken into consideration. To meet all the criteria requires an innovative curriculum design that will meet the needs of both Higher Education and Industry. The new capstone projects will be tested in the existing curriculum. This paper will address how we align theory learned with project-based learning to bring together intellectual enquiry, real-life problems and student engagement in meaningful work. It is shown how students apply their knowledge in the Greenhouse Control Industrial Project, a 360-hour capstone project, where programmable logic controllers (PLCs), variable speed drives (VSDs) and Human Machine Interfacing (HMI) will be used to control flow, temperature and humidity in a greenhouse application.

II. ENGINEERING COUNCIL OF SOUTH AFRICA (ECSA)

The Engineering Council of South Africa (ECSA) [4] is a statutory body established in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000). Apart from administrative provisions, the Act is aimed at promoting safety, health and interests of the public in relation to the engineering work and professional conduct of persons registered with ECSA. In order to achieve the Act's main focus, ECSA is empowered to perform a variety of functions. An ECSA function greatly impacting on UNISA's School of Engineering is the setting and auditing of academic standards for purposes of registration through a process of accreditation of engineering programmes at universities and universities of technology. ECSA must conduct accreditation visits to all educational institutions offering engineering qualifications at least once during its term of Council (four years). ECSA must either conditionally or unconditionally grant, refuse or withdraw accreditation for engineering programmes at educational institutions. This duty is performed in consultation with the Council on Higher Education (CHE) [5&6]. ECSA [4] carries out accreditation of programmes offered by universities of technology and comprehensive universities in order to:

- establish whether the qualifications awarded from the programmes meet the educational requirements leading towards registration as Professional Engineering Technologists, Professional Certificated Engineers or Professional Engineering Technicians;
- establish whether the diplomates or graduates from the respective programmes are ready for employment and are equipped to continue learning throughout their careers;
- establish international comparability of the programmes;
- assure the public of the quality of the programmes;
- encourage improvement and innovation in engineering education in response to national and global needs.

- Due to ECSA's international worldwide accords [2], accredited qualifications allow for international recognition of students' qualifications.

III. AUTOMATION AND CONTROL

Automation is the controlled operation of an industrial process, designed to replace human operators. Automation has allowed Industry to make processes safer and more efficient in the most cost-effective way. A Programmable Logic Controller (PLC) is used in the automation of industrial processes. It is a robust digital computer, designed for tough industrial operation. A process consists of receiving information (inputs), making a decision (PLC) and acting on the decision (outputs).

- PLCs are covered in several Control and Process Instrumentation modules. By introducing basic concepts in the first year of study, and building on that knowledge through each level, students will eventually progress to a stage where they are able to complete actual real-life industrial tasks, making use of the same equipment and software employed in Industry. Students can test and verify that their control applications function correctly by simulating it on computer until they are ready to download it onto the actual equipment.
- A typical first-year project would entail writing a PLC program for a start stop circuit for a motor, a second-year project for a star delta circuit, while third-year students could write PLC programs for a traffic controller or a sequential starter for a conveyer belt. The project consists of inputs (switches, sensors, interlocks etc.), the processing section where the user can customise the process by means of programming, and the output section wired to the output relays. The output relays can then be connected to contactors to switch on motors or pumps as required. Inputs and outputs can be isolated by opto-couplers to protect the PLC from external faults. All these designs include the required safety interlocks and features. For the new capstone project in plant automation, students are required to design a control application for temperature, humidity and flow control in a greenhouse [7].

IV. CAPSTONE PROJECTS

Industrial Projects is a compulsory BTech degree subject. It contributes 30% towards the BTech qualification [5]. It is an important part of the degree, since it is the subject where students apply their knowledge of different subject areas to one particular project. It is for this reason that students are required to have completed a significant portion of technical subjects before enrolling for this subject. The amount of time allocated to the project gives the student and employer a rough estimate of the type of project that should be chosen. It is required that at least 360 hours be spent on this project. Ideally, a student must operate in a working environment where they will be able to select a suitable project and carry out the design and experimental evaluation at the workplace, making use of the employer's resources. The employer will therefore have to be supportive and allow the student the necessary time to spend on the project. This subject assesses the following graduate attributes required by ECSA: problem solving, application of scientific and engineering principles, engineering design, the impact of engineering activity and engineering professionalism.

4.1 Industrial Projects

The first step towards the successful completion of the Industrial Projects subject is identifying a suitable project. Students enrolled for this subject are provided with details of the greenhouse automation project.

Three factors that need to be considered when identifying a suitable project are:

- student's field of expertise/interest;
- needs of the employer/technical environment;
- mentor's expertise and guidance.

An experimental group of sixteen students are currently working on the real-life greenhouse project and have been provided with the specifications and control requirements/ranges for temperature, humidity and flow.

4.2 Conceptual Design Report [8] (Progress Report 1)

This is the first progress report and it must be submitted within two months after registration. The report must include the following:

- background to the problem;
- User Requirement Specification (URS) (technical specification of what is required);
- concept study (investigation and evaluation of various concepts or possible solutions);
- decision-making matrix (comparison of different concepts in terms of advantages and disadvantages);
- bibliography.

The report must end off with a clear choice of one of the concepts. The chosen concept will then form the basis of the detailed design, which is the topic of the next progress report.

4.3 Detailed Design Report [8] (Progress Report 2)

The second progress report must be submitted within four months after registration. This report must include the following:

- background problem statement, URS and the chosen concept;
- technical specification of the selected concept (how will the system meet the requirements?);
- detailed (engineering) design;

- test procedure explaining how the design will be tested and evaluated to ascertain whether it meets the requirements;
- design implementation schedule;
- bibliography.

4.4 Report on Design Implementation [8] (Progress report 3)

The third progress report must be submitted within seven months after registration. This report must include the following:

- background to the project;
- discussion of implementation processes, problems encountered and solutions devised;
- evaluation/testing procedures of the system or subsystems;
- fault finding and improvements to the design;
- bibliography.

4.5 Final Report [8]

The final report, neatly typed and bound, must be submitted nine months after registration. This report comprises the thesis and must include the following:

- Title page, Executive summary, Table of contents, Lists of Abbreviations, Symbols, Figures and Tables
- Main body covering the contents of Progress reports 1, 2 and 3
- Results, Analysis of Results, Discussions, Conclusions, Recommendations, Bibliography and Appendices
- All reports are to be neatly typed and bound prior to submission.

4.6 Evaluation of Engineering Projects

The final evaluation of the subject is based on a year mark and an examination mark. The year mark is earned through the three progress reports. The examination mark is earned through the final report and an oral presentation/examination. The oral examination is conducted once the quality of the final report is acceptable. The examination mark is determined according to the following evaluation schedule:

Students have to take readings and analyse the results. Functionality is a very important part of the project and counts 30% of the final mark. Assessment is integral to effective curriculum design and the implementation of this capstone project. Students are therefore required to present their projects at the end of the year to a panel of evaluators. During the oral examination the student is expected to demonstrate the project. Should the project be of such a nature that it cannot be transported, the oral examination may be conducted at the student's workplace. In exceptional circumstances, the student may be allowed to conduct an oral examination with photographs or video clips providing sufficient proof.

Table 1: Final Mark Composition [7]

Yearmark	20%
Functionality	30%
Presentation	15%
Portfolio	35%
Total	100%

V. TRAINING PROVIDED FOR GREENHOUSE CAPSTONE PROJECT

Advances in technology have made it possible to include simulated learning for Programmable Logic Controllers (PLCs), Variable Speed Drives (VSDs) and Human Machine Interfaces (HMIs) to form part of our Automation capstone project. In 2018, sixteen students were provided with simulation software to be able to work on their projects off-campus and also to prepare for four 2-day training sessions on the actual equipment on-campus. This allowed student to submit project work online. Once they completed their work, they could link their programmes to the actual equipment on-campus for final testing. After they had completed the training, the students were required to submit three possible solutions to the greenhouse application.

The four 2-day training sessions, presented during the course of the project, covered:

- Easy Programmable Logic Controllers (PLCs) training, during which students learn to program in Ladder Diagram (LD). A second session covers timers, counters and markers.
- XC Programmable Logic Controllers (PLCs) training, during which students learn to program in Instruction List (IL) and Function Block Diagram (FBD). The second session covers analogue signals and Proportional Integral Derivative (PID) loops.
- Human Machine Interface (HMI) training, during which students learn to program in Galileo. This covers touch screen control and visualisation.
- Variable speed drives (VSDs) training, during which students learn to control the speed of an induction motor safely and for different applications.



Figure 1: Plc Software



Figure 2: Actual equipment

VI. RESULTS AND THE WAY FORWARD

All UNISA students enrolled for the BTech degree in the School of Engineering need to successfully complete a capstone project to be able to graduate. A group of sixteen students are currently participating in a 360-hour Greenhouse Control Industrial Project. The main aim of the study was to determine how successful the real-life applications, training, support, feedback sessions and marking rubrics have been with regards to this test group. This information will enable the improvement of the capstone projects as well as the qualification as a whole. Additional information was gathered by making use of exploratory research and observations. A questionnaire was developed, consisting of both closed and open-ended questions, to determine the challenges and opportunities the Engineering students experienced while making use of the PLCs, HMIs, VSDs and simulation software packages. Students were also asked what they liked about the capstone project in Automation. This information will be used to improve the new qualifications that are being implemented in 2020. There has been a significant increase in the number of students who were able to get the real-life project in Plant Automation to be functional in 2018 (refer to Fig. 3).



Figure 3: Number of students achieving functional project

A total of 305 students enrolled for Industrial Projects in Electrical Engineering at UNISA for 2018. At this stage, 58 students have already cancelled registration this year (refer to Fig. 4).

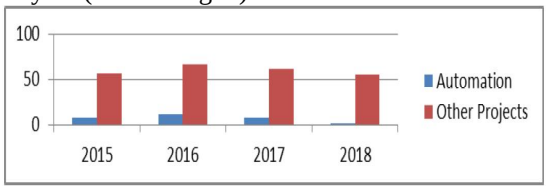


Figure 4: Number of students cancelling registration of capstone projects

UNISA's language of tuition is exclusively English. Most students therefore receive tuition in a language other than their mother tongue (refer to Fig.5).

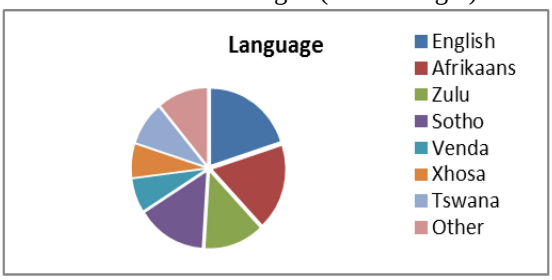


Figure 5: Languages spoken by students registered for capstone projects in 2018

CONCLUSION

UNISA being an open and distance learning institution, we are always looking into better and more efficient ways to support our students in their studies. Currently, the Department of Electrical Engineering are engaged in compiling instructional DVDs to demonstrate the use of PLCs, and also in training students to use simulation software for their capstone projects. The introduction of suitable simulation software have enabled students to make use of the actual automation systems employed by Industry, to solve real-life electrical automation problems, to learn fault finding techniques as well as reporting skills, and to work with other members in a team approach in preparation for the workplace. The students' understanding of real-life electrical projects, the quality of reporting as well as results have improved since the introduction of the training, support classes and assessment rubrics. Representatives of the Electrical Engineering Advisory Board have indicated their support of these initiatives. We intend establishing additional partnerships with Industry for other areas of specialisation within the Electrical Engineering discipline to the benefit of students, UNISA and Industry. Modules relevant to the workplace will equip students with the knowledge and skills required in Industry and will better prepare them for what they will encounter in the workplace.

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