INTEGRATION OF MICROPROCESSOR TECHNOLOGY INTO ENERGY CONVERSION / ELECTRICAL MACHINES COURSES

Edward Chikuni[1], and Jacques du Toit[2]

Abstract *— Advances in microprocessors and micro controller technologies have brought with them many opportunities. These opportunities are being exploited to great economic benefit in the developed world and to a lesser extend by developing countries. At the same time the nature of our industrial plants is changing and computer chips are encountered even in the most elementary equipment. However many educational institutions still approach the teaching of electrical power courses with little attention to these vital new realities with the result that graduates are technologically handicapped when they enter the world of work. This paper sets out to analyze the situation at the University of Zimbabwe and Cape Technikon, South Africa and proceeds to propose new solutions.*

Index Terms — Curriculum Review, Microprocessor Applications, Teaching Aids

1. INTRODUCTION

The engineering profession has been considered by many, including the profession itself, in terms of distinct disciplines and indeed for a long time, the triad consisting of Civil, Electrical and Mechanical Engineering was central to engineering faculties in the 'British' Commonwealth. Today however the number of disciplines under 'engineering' has more than doubled and we begin to see new subject areas as a result of 'breaking away' from their cores, for example, Computer Engineering and Communications becoming degree courses in their own right instead of being part of an Electrical Engineering Degree Curriculum. These new developments have very important implications for the traditional enterprises, which produce services in particular, the manufacturing, communications and transport sectors. The boom in the Information Technology (IT) sector has resulted in unprecedented demand graduates with computer skills in particular computer engineering (imbedded systems) software engineering (JAVA, C++ , etc.). The level of remuneration by the IT industry is presently such that more undergraduate students choose computer and electronics related options than electrical power engineering options. However all over the world it is found that our production, and transport sectors are very energy intensive and they utilize electrical and mechanical machinery that requires a good understanding of the fundamentals of electrical machines and energy conversion. This means that to maintain plant that incorporates traditional drives systems and motors as well as microprocessor / micro controller technologies, a unified approach to learning is now mandatory.

2. PRESENT STATUS IN THE INSTITUTIONS

2.1 University of Zimbabwe (UZ) (4 year BSc. (Eng.)

The Department of Electrical Engineering at the UZ is small compared to others in the region. The average first year intake is 40 (200 in some South African Universities). The selection criteria is based on Cambridge Examination 'A' level points. Applicants with 12 or more 'A' level points (e.g. grades A, B, C or B, B, B) from 3 eligible subjects stand a very good chance of entry. Two or three (5-8%) of the first year students are admitted on the basis of a mature entry scheme which aims to give opportunities to those applicants with alternative qualifications, for example a recognized diploma together with industrial experience. The numbers of students admitted into Engineering is limited in accordance with available facilities which means that many qualifying students are unable to secure a place. The first year curriculum is largely common among civil, electrical, geo-informatics & survey, mechanical, metallurgy and mining students. In the first year students study mathematics, computer science, electrical principles, communication skills, engineering drawing, engineering materials, and mechanics. Students should pass at least seven of these eight subjects before proceeding to the second year. The failed subject has to be passed in the next examination for that subject before he or she is allowed to proceed to the 3rd year. In the second year student will formally belong to specific departments. For those registered in Electrical Engineering, they will take 8 courses of which 6 are offered by the department and 2, Mathematics and either Thermo Fluids or Applied Mechanics are offered by the departments of Mathematics and Mechanical Engineering respectively. The Electrical Machines course (EE202) is taken by about 110 students annually, from Electrical, Mechanical, Mining and Agricultural Engineering.

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Experience has shown that the large size of the class imposes particular challenges to lecturers. Also, it is difficult to do remedial work to those students who may find the subject matter difficult. In this paper the authors will be addressing not only the course review, but also the question of large classes that concerns all institutions in the region (especially South Africa, as a result of the opening of the institutions to the general population).

2.1 Cape Technikon (CTECH)

Cape Technikon offers the National Diploma and the BTech degree in Electrical Engineering. For entry into the National Diploma Course, a 50% pass is required in Matric Standard Grade or 40% in Matric Higher Grade Examinations. The students can specialize in Computer Engineering, Power Engineering, Industrial Electronic Engineering and Communications Engineering. The duration of the National Diploma is 6 semesters. The first four semesters are spent full-time on campus and the remaining 2 semesters in industry. During the full-time campus period the student must successfully complete 20 credits of course-work. During this period the subjects of Electrical Engineering 1&2, Electronics 1&2, Mathematics 1&2 and Machines 2, Projects 1, Digital Systems 1&2 and Communication Skills are compulsory subject choices. The student selects the remaining subjects of his/her choice subject to course pre-requisites and timetable constraints. A subject carries a weight of 1 credit. A typical subject consists of theory lectures (50 hours), practical laboratory sessions (20 hours) and assignments (20 hours). Student performance is assessed by course-work (tests, assignments and laboratory work) and a 3-hour examination for each subject. The final mark is aggregated on the basis of a weighting of 40% for course-work and 60% for the final examination. The focus assessment is on application of theory and 'Open Book', type of tests and examinations conducted in some subject areas. The entry requirements of the BTech degree is a National Diploma in Electrical Engineering with an average pass mark of 65%. The BTech degree course requires total of 10 credits from four areas of specialization, namely, Communications Electronics, Computer Systems, Industrial Electronics and Power Engineering, as well as the Project (3 Credits).

3. ELECTRICAL MACHINES COURSES AT THE UZ AND CTECH

3.1 Brief Course Outline

In this paper the authors will be focusing on the Electrical Machines courses taught to students at the two institutions and draw some parallels between them. For the UZ the aim is to impart them sufficient material to enable understand the theory, important design principles and applications of electrical machinery. For CTECH, the emphasis is on practical application and the use of more routine design procedures using common formulas or tables. The topics and approach for the courses are as follows:

- Principles (Physics) of operation for the most common devices such as transformers, electric motors and generators.
- More detailed treatment of each of the machines in particular, DC machines, Transformers and Induction Motors. The UZ treatment is more rigorous with many results obtained from first principles.
- When studying the above courses concepts of efficiency and the limitations of each machine are given.
- At the UZ concepts such as power factor correction and phase sequence are introduced for the benefit of students from other departments.
- A number of Laboratory Exercises are to be done by each student. Because of limitations in equipment, students work in groups some times more than 10 in a group. Each student is supposed to produce a laboratory report in accordance with a given format.
- Tutorials and assignments form part of the students learning experience. Assignments, Tests and Laboratories are assessed and together these have a weighting of no less than 25% (at UZ) of the student's overall mark in an examination, or (40%) at the Cape Technikon.
- At the UZ the course consists of 60 one-hour lectures plus the laboratories and tutorials (covered in one semester).
- There is one 3-hour examination.

3.2 Weaknesses in the above format

3.2.1 Course Structure

Although some attempts have been made to modernize the material in each topic, the structure itself has changed little over the past 10 years. Meanwhile the technology used to control and protect electrical machinery in modern plants has changed to the extent where only those people with new skills are required. In South Africa the demand for both Electrical Engineers and IT specialists still remains unfulfilled Table 1 based an article in the Sunday News [1].

3.2.2 Too Large Class Sizes

It has been experienced that with large classes the student learning experience is stifled because of insufficient time with the lecturer trying to make sure that all the course material. On the other hand it is difficult to identify those students who may be experiencing difficulties as feel too intimidated to ask questions. It has also been found that those students who believe they already know a particular topic make noise for the others and in a large class it may be difficult to identify them.

TABLE 1

S. AFRICA HIGH-LEVEL SKILLS REQUIREMENTS

Discipline	Projected Growth in Demand, 1998-2003	No of Positions to be filled, 1998-2003
Information Tech	40%+	20 000
Elect/ Chem Eng	40%	2 500
Chart. Acc.	40%	5 000-8 000
Investment Professionals	15-40%	5 000-8 000
Actuaries	15-40%+	250
Medical Pract.	10-15%	500
Nurses	5-10%	16 000-20 000
Natural Sc. Technologists & Technicians	10-15%	1 000-2 000

4. PROPOSED STRATEGY

Microprocessors and micro-controllers are used in a number of disciplines ranging from communications to energy systems engineering and therefore it would not be appropriate to incorporate the full contents of what is presently a microprocessor course into an electrical machines / energy conversion course. Most power engineers are interested in the applications aspect of microprocessors / micro-controllers rather than detailed aspects of microprocessor architecture. Industry is also looking for affordable technology that has the potential of reducing costs and increasing reliability. The approach being suggested is a combination of software and hardware that:

- Reduces the requirement for detailed hardware knowledge, less steep learning curve.
- Reduces the requirement detailed programming and software know-how.
- Allows the assessment of the potential of microprocessor-based solutions for a wide range of production and technology-based service industries such as railways.
- Can fit within the requirements of typical course unit with respect to teaching time and laboratories.

In addition to the hardware and software aspects above, there is also a need to present a revised course that accommodates the new material without over-compromising cornerstone course material in the electrical machines / energy conversion. To do this requires reflection and analysis from higher levels of the department. Figure 1 gives a suggested approach:

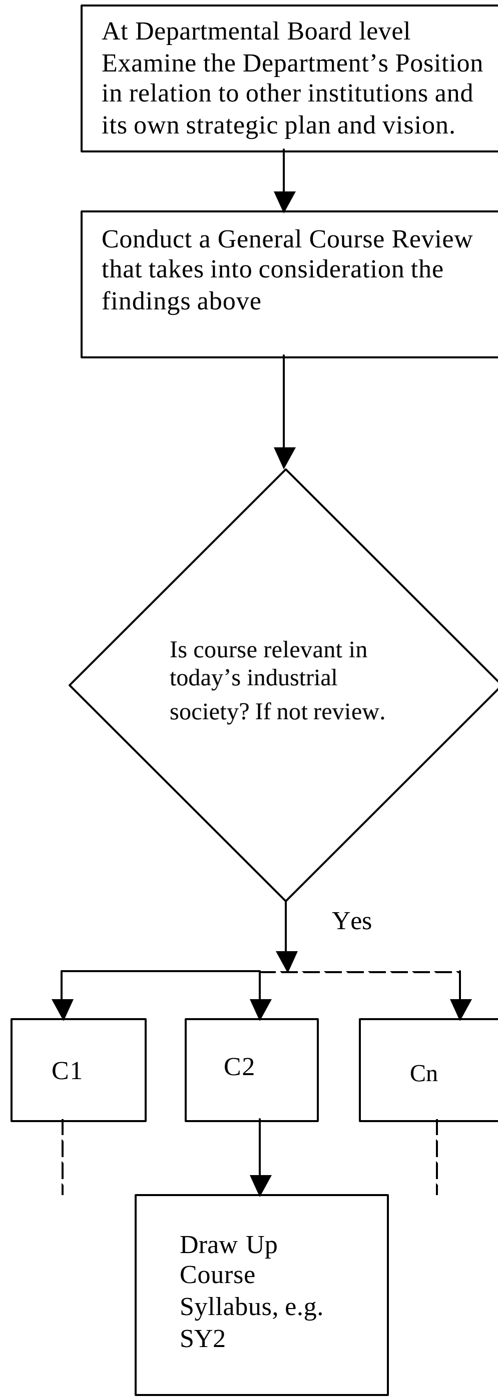

Figure 1

5. REVIEW OF MICRO-PROCESSOR TRAINING SYSTEMS

The industry has always recognized the need to promote the use of microprocessors since they were first used in the first personal computers in the late 70's (e.g. Commodore PET, TRS 80, APPLE, ALTAIR (Bill Gates and Paul Allen wrote the programming language for ALTAIR, *ALTAIR BASIC* in 1975). There were also self-built computer kits e.g. Nascom 2, Sinclair ZX. At about that time computer boards similar to what are called development systems today were also available, some targeted at the educational sector. The most prominent personal computers used either Motorola or Intel processors (6502 or 8080). Instruction compatible chips followed, notably the Zilog range that could not only handle the 8080 instruction set but additional instructions. The development systems that were available would have additional circuitry to incorporate items such as counter / timers, I/O and memory. As a result of progressive miniaturization, the size of microprocessor development systems has shrunk considerably and a lot more features can be packaged on a small board. Compare the older bigger board of the early era with the smaller more functional one alongside it in Fig. 2. The Intel 8051, the PIC, and the Motorola MH68C11 family of micro-controllers are now deployed in a large number of appliances and systems today, this time as part of what are called imbedded systems.

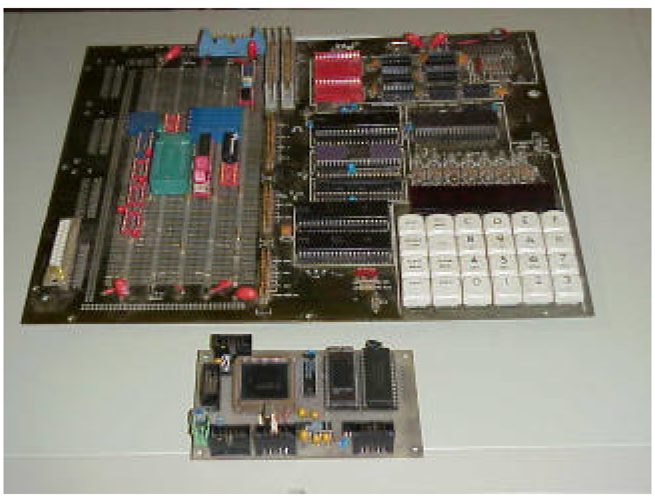

Figure 2: Old and New Development Systems

6. ATTRIBUTES OF A DEVELOPMENT SYSTEM SUITABLE FOR ELECTRICAL MACHINES / POWER DOMAIN

Most micro-controller varieties incorporate memory (RAM & ROM), A/D converters as well as input / output ports. In addition to these attributes there are also capabilities that would be necessary in order to demonstrate the synergies between the machines and the processors. For electrical machines such as motors it would be beneficial if it were possible to achieve the following:

(a) To activate power devices, such as contactors.

(b) To measure operating parameters, such as speed, current, temperature.

(c) To control operating requirements such as speed, torque or tractive effort.

For (a) we would require that the system possesses a number of digital I/O channels. The measuring capability in (b) requires the use of an A/D capability that, fortunately, is standard in the current generation of micro-controllers. Attribute (c) can be realized through a combination of hardware and software using standard micro-controller versions. However increasingly products are available which offer enhancements to certain microprocessor families. These enhancements include increased ROM, FLASH ROM and RAM. More significantly, useful functions such as PWM are now part of the microprocessor hardware. This function simplifies programming and hardware related tasks and therefore micro-controllers with this function should be seriously considered to address the requirements of (c).

7. SYSTEMS AVAILABLE IN THE MARKET

Many microprocessors companies offer evaluation boards some targeted at the educational sector. Among these are Intel, Philips, Siemens, Motorola and Microchip Technology. Examples of systems available are given below:

7.1 PIC Based Systems

For some years the PIC micro-controller has offered affordable solutions in the imbedded systems environment within the realm of process control, and security devices. One version of the PIC processor with attractive features in the motor and power device control is the PIC17C756. This has 50 I/O lines, sets of timer/counters two universal synchronous interfaces (USART/SCI). Basic control of electrical machines can be achieved through the use of three PMW outputs that have a resolution of 1-10 bits. A development board based on this processor is described in Elector [4]. This PIC is available from manufacturers / suppliers such as Microchip Technologies and Philips.

7.2 8051 Based Systems

The 8051 microprocessor has been very successfully marketed and is used for many imbedded applications. There are also many user groups and support is quite extensive. For control of electrical machines and power related devices, enhanced versions are available. The 80C515 features many of them similar to the PIC17C756 described above. The *80C515* on board Timer 2's additional compare/capture/reload feature is particularly powerful and is used for all kinds of digital signal generation and event capturing such as pulse generation, pulse width modulation, pulse width measuring etc. This allows various automotive control applications (ignition/injection-control, anti-lock-brake) as well as industrial applications (DC-, three-phase AC- and stepper-motor control, frequency generation, digital-to-analog conversion, process control).

Timer 2 in combination with the compare/capture/reload registers allows the following modes:

- Compare: up to 4 PWM signals with 65535 steps at maximum, and 1 msec resolution.
- Capture: up to 4 high speed inputs with 1 msec resolution
- Reload: modulation of timer 2 cycle time

7.3 Motorola 68HC11 and Other Systems

The number of microprocessor / micro-controller development systems options available is considerable. Motorola 68HC11 based evaluation boards with enhanced features similar to those mentioned above are in common use as are DSP processor systems from Texas Instruments.

8. INTERFACING TO EXTERNAL DEVICES

Once a particular development system is selected, there is still a need to interface it to devices for which it is programmed for. Focusing the system's application as a tool to familiarize students aspiring to be power engineers we would need to include as part of the interface system items such as:

(a) Measurement and signal conditioning circuits and components. This would include divider networks, operational amplifiers and transducers as required by the application.
(b) Galvanic isolation components to isolate high voltages and signals from the usually low voltage circuits associated with microprocessors.
(c) Driver / amplifier circuits as well components to allow the operation of high power equipment from low power / voltage signals. The components could include power MOSFETS, IBJT's, TRIACS and relays.

Figure 3 shows a general layout of development system with interface components.

9. DEVELOPMENT SOFTWARE

The concept propounded in this paper is that the students on an electrical machines course would be required to assimilate only that knowledge necessary for the implementation of microprocessor / micro-controller based solutions for a particular problem / scenario and to do this in the most efficient manner. They would not be expected to be fully-fledged software engineers, although some may, indeed, elect to do so.

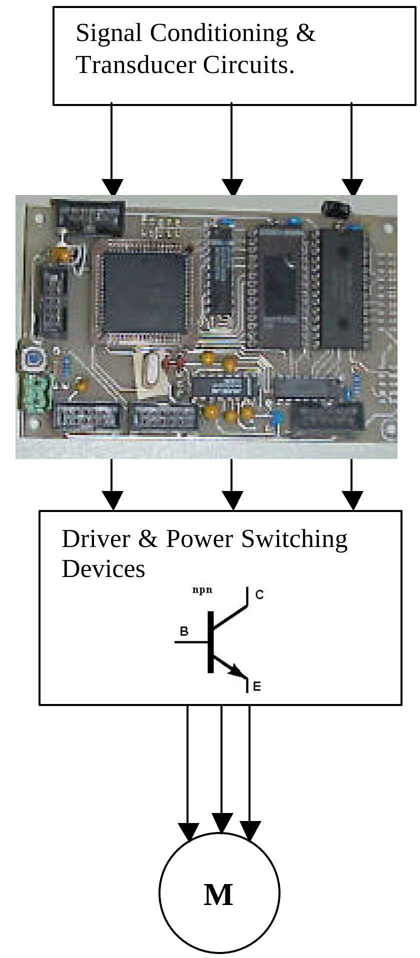

Figure 3: Evaluation Board in Motor Drive Application

Depending on the requirements software can be written in a high level language such as C++ or assembler. A number of software development aids are now also available, some optimized for a particular processor. The software burden is now increasingly lessened especially with Integrated Development Environment (IDE) software bundled with micro-controllers offered by some manufacturers (e.g. Keil µVision by Keil Electronik, GmbH, Germany). Processor simulators (e.g. DAvE, -Digital Applications Engineer from Siemens) are particularly useful for the academic environment in the sense that a student can prototype a project in software and only build hardware after it has been established that it is feasible in software. Siemens also have software a development tool that allows easier development of C based applications (EasyCode).

10. KEY POINTS FOR NEW COURSES

The integration of new study material into an existing course will immediately pose questions as to how the new material will fit in within the time frame allowed for that particular course. This and other constraints can be handled by taking in to consideration the following:

(a) The need review the existing course with the objective of making it more concise without compromising standards. This may be done by removing obsolete material or by re-assigning it to related courses.
(b) The availability of modern software tools, e.g. spreadsheets CAD and interactive multi-media [5]. These remove the tedium out of machine problems and allow the student to focus on the principles.
(c) The use of the on-line learning environment that allows students to take certain parts of courses and exercises through the Internet / or departmental Intranet (Power [5]).
(d) The use of short seminars / courses outside the normal teaching hours. These seminars /courses would be eligible for credit.

11. CONCLUSIONS

The Authors have set out to bring to focus the teaching of Electrical Power Engineering in many institutions today, with particular emphasis on Electrical Machines / Energy Conversion. There is increasing interest by students to major in microprocessors, computers or IT in line with the employment market and lesser interest in the "Heavy" Electrical Engineering options such as machines or power systems. However, Engineering is all about technical problem solving, and the equipment that powers our plants today is multidisciplinary. We therefore require engineers that are adequately prepared to tackle problems that are of a multidisciplinary nature. Imbedded systems and their software should in time become 'common knowledge' among electrical engineers. Indeed there is a trend among employers to hire software or systems engineers who have good understanding of the systems that they are developing software for. There is considerable hardware and software available and suitable combinations can be selected to meet particular teaching requirements. Clearly it would be wise to choose hardware and software platforms that are common in the industry so that graduate can quickly adapt to the technological environment of their work place. Integrating microprocessor know-how into an existing course should only be done after a thorough review of the existing course during which obsolete or superfluous material is removed. There is also a need to take advantage of modern software and simulation tools to make the teaching process more efficient and to make use of emerging technologies such as the Internet.

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