Integrated Instrumentation and Control for Mechanical and Electrical Engineering Technology

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Abstract

Instrumentation, measurement and control involving modern industrial processes have evolved significantly during past few decades. Availability of smart sensors and fast data acquisition, processing and control technology have integrated instrumentation and control to a more cost effective, speedy and reliable process. To address industry need in the skill of engineering graduates as well as practicing engineers/technicians, a modular curriculum and laboratory is being developed in the subject area. These modules are (a) modern industrial processes, (b) sensors and transducers, (c) data acquisition and data processing, (d) process control, and (e) integrated measurement, data acquisition and control. This modular curriculum is designed to fulfill the need for two and four year undergraduate programs in mechanical engineering technology (MET) and electrical engineering technology (EET), as well as training industrial professionals. By varying the emphasis on each module, the same curriculum and laboratory may be used for each category of audience. While MET programs will emphasize more module (a), (b) and (e); EET students will focus more on module (c), (d) and (e). Training programs for industry professionals will be customized case by case. The laboratory consists of LavVolt process stations, actuators drives, commercially available sensors/transducers, National Instrument data acquisition hardware and PC with LabVIEW software. This NSF sponsored project is scheduled for completion by June 2000.

1. Introduction

Traditionally, mechanical and electrical engineering technology programs have been using separate courses in instrumentation, measurement and control area to achieve respective program goals. During past two decades, instrumentation technology has changed rapidly and distinction between mechanical and electrical instrumentation is gradually fading. Based on input from industry, we find that market wants more interdisciplinary skill among engineering and technology graduates. To keep pace with this change, engineering and engineering technology programs are upgrading their curriculum continuously [1-3]. Two-year institutions are behind in this regard due to

program objective, student background and time constraint besides other reasons. During 1997, as the college was preparing to switch from quarter to semester system, it was decided that need for instrumentation and control courses of both MET and EET programs should be revisited. The result was to develop a joint course for both the programs meeting these key objectives:
(i) Reflect recent advancement in this field
(ii) Fit the diverse nature of student body
(iii) Develop cost effective laboratory.

This new curriculum should introduce the skill required to deal with installation, operation, modification, expansion, trouble shooting and maintenance of existing systems rather than design/analysis of new systems. Most significant challenge was to design the curriculum to fit a very diverse group of students with different background and objectives, some of which are conflicting at times. Based on past experience, an effective way to address this problem would be to modularize the curriculum and remain flexible in course and lab content based on student need within the broad range of program objectives. Besides development of this new curriculum, a parallel plan was developed to monitor its success by measuring outcomes of the students in both programs. This data would help to enhance effectiveness of the curriculum in future. A customized version of the curriculum model will also be used by Unified Technology Center of the college to train industrial personnel.

2. Background of MET and EET programs at CCC

CCC is an open door urban community college with a large diverse student population. MET and EET programs of CCC offer two year associate degree as well as one year certificates in specific area of study. Unified Technology Center (UTC) of the college offers noncredit courses in various areas for training of industrial personnel.

Student diversity in the programs arises from their socio-economic background, age, prior education, aptitude level, math-science background and educational objective among others. About third of the students are regular high school graduates while others are working full or part time and returning to school after a break in study. Significant number of these students takes classes only to enhance their skill in specific areas for professional enrichment. One third of the students either complete a degree or take specific classes to transfer to a four-year institution. Percentage of students taking only individual classes, especially, in the evening, is on the rise. During last five years about fifty percent of the students enrolled in instrumentation and control classes of MET and EET programs actually graduated with a degree.

3. Overview of old instrumentation curriculum

Prior to fall 1998, MET and EET programs of CCC used to offer separate courses in instrumentation, measurement and control area. These are MECH 221, ELEC 262 and ELEC 263 as shown below.

MECH 221 (Applied instrumentation, measurement and control)
Quarter credit hour: 3.0 Lecture: 2 hours. Lab: 4.0 hours
Topic: Measurement of pressure, temperature, flow rate, viscosity, level, humidity, motion and force and introduction to process control.

ELEC 262 (Electronic measurement)
Quarter credit hour: 3.0 Lecture: 2 hours. Lab: 2.0 hours
Topic: Electronic measurement, test equipment, meters, oscilloscope, instrument calibration and instrument circuits.

ELEC 263 (Electronic instrumentation)
Quarter credit hour: 3.0 Lecture: 2 hours. Lab: 2.0 hours
Topic: Measurement circuits, impedance bridge, signal generator, transducer and data recorder.

While mechanical curriculum lacked use of electrical/electronic instrumentation and computer assisted processes, electrical curriculum did not cover realistic industrial processes, which may use both mechanical and electrical elements for measurement and control.

4. New instrumentation curriculum

During fall 1998 transition to semester system, EET 2600 (Instrumentation and Control) was developed as a new three-semester hour course with weekly 2 hours of lecture and 4 hours of laboratory exercises. The emphasis was on the use of modern sensors, transducers, data acquisition system and computer controlled processes simulating industrial applications. Broad student performance objective of this new course is:

(i) Understand measurement, instrumentation, its characteristics, errors and calibration.
(ii) Understand and able to use methods of measurement data collection, processing, conversion and analysis for display, record and process control.
(iii) Understand design, principle of operation and use of electrical and mechanical sensors and transducers.
(iv) Use instruments to measure force, pressure, temperature, fluid level, flow rate, viscosity and motion as process variables.
(v) Understand control principle, modes and technique of process control.

Realizing these objectives with the constraints involving student background, available time and facility is quite challenging. To achieve similar objectives in instrumentation area, some institutions break up topics in series of course [4]. Considering all constraints, at CCC, student diversity was found to be most challenging for this curriculum development.
Modular curriculum and flexibility in class and laboratory exercises within the broad scope of the program objective accommodates well with a diverse student body. This

adjustment in teaching can be implemented using student background data prior to beginning of semester during registration for the class. This would allow us to use same resource for a large diverse group of audience in MET, EET programs and UTC's industrial training.

The new instrumentation and control curriculum was divided in five modules. Module (a) introduces students with modern industrial process and need for process variable measurement. As an introductory module, every student should be familiar with this prior to starting another module. In module (b) students learn mechanics of sensors, transducers, measurement circuits and their usage. Module (c) covers data form, data acquisition and data processing analysis. The depth of coverage can vary based on orientation of student background. Student with programming and electrical background can explore this module in more detail. Control theory, required hardware and implementation of various control modes is taught in module (d). Mathematical implication of control is beyond the scope of most two-year programs, but this can be explored more in a four-year instrumentation curriculum. Module (e) is designed to teach integrated measurement instrumentation and control. More details of the curriculum are shown in the Appendix. The course is designed as a fourth semester course with prerequisite of physics and industrial electronics for MET students. At that level students are also experienced with programming (such as in Visual Basic) and computer usage in various technical applications. EET students should already have appropriate background in circuits and electronics from other required courses in the program.

5. Laboratory

Using a National Science Foundation ILI grant, the laboratory is in the process of development. It contains LabVolt pressure module PM-1, flow/level modules FML-1 and FML-2, temperature module TM-1, control panel module CPM-1 and a calibration bench [5]. The pressure module creates single or dual capacity airflow with interactive demand supply disturbance at various loop configurations. The flow/level modules consist of water based flow loop involving liquid flow rate, level and motor speed as process variables. The temperature module has an electric water heater, two heat exchangers, a variable speed fan and two pumps. All units are connected to the control panel module for electrical power/ pneumatic pressure connection as well as signal interconnections. A typical process diagram is shown in figure 1. All the process stations can be interconnected to create complex process loop for multivariable control. The calibration bench has pneumatic pressure regulator/input, 120V ac 15 amp, 24 V dc 2 amp power supply with digital instrument calibrator millivolt, milliamp and volt inputs.

All process sensors and actuators will be connected to National Instrument data acquisition (NIDAQ) hardware and personal computers. These include SCXI 2000 and SCXI 1200 data acquisition modules, SCXI 1124 D/A converter, SCXI 1102 multiplexer, terminal blocks, serial/parallel interface and LabVIEW software [6,7]. This is shown by a block diagram in figure 2. Measurement of process variables, data processing, analysis and control will be executed using NIDAQ and LabVIEW system.

Students will also be able to develop Virtual Instrumentation (VI) before actual process implementation. Compared to a hardwired complete system, this mix of different components will help students to learn and appreciate principles, function and use of such system in general. This also makes the project cost effective compared to other options and creates possibility of future expansion and diverse use of the laboratory.

6. Student outcomes measurement

Both MET and EET programs have developed plan for assessment of student outcomes and collect data in various cyclic forms for annual review. Students taking EET 2500 class will be assessed as part of this process. Following data will be collected from every student taking the course.

A. Student survey on :
   - (i) educational goals
   - (ii) current educational status
   - (iii) current employment

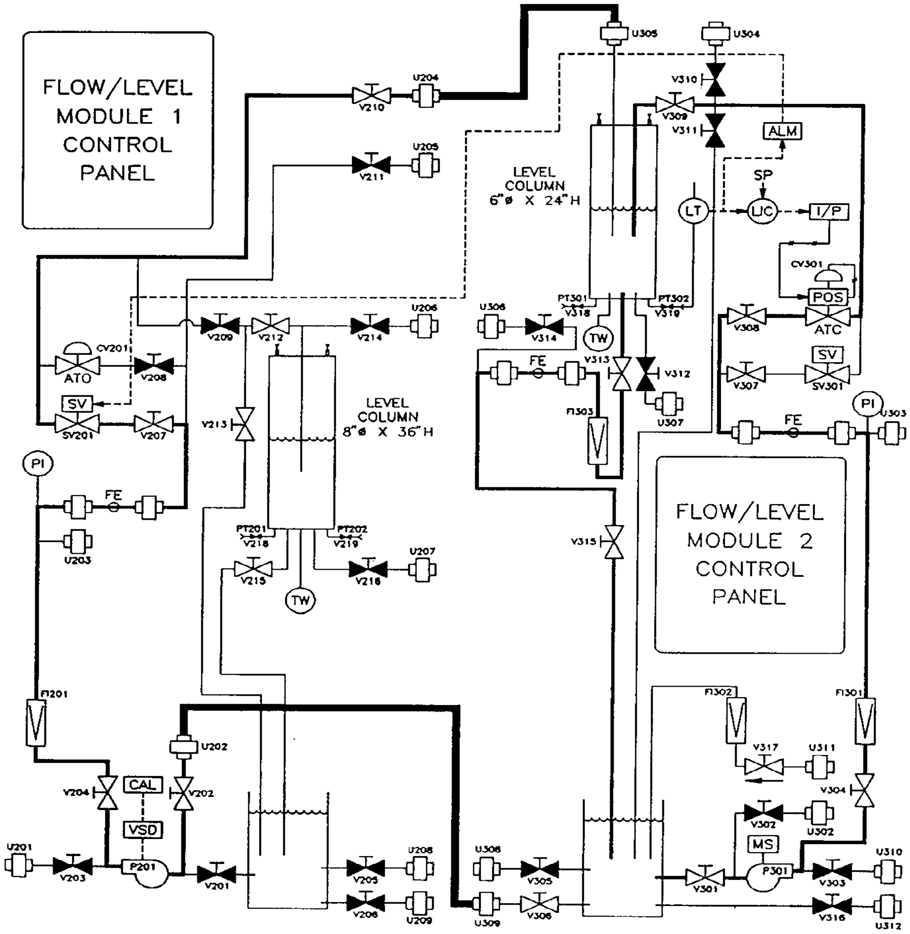

Figure 1
A typical process diagram.

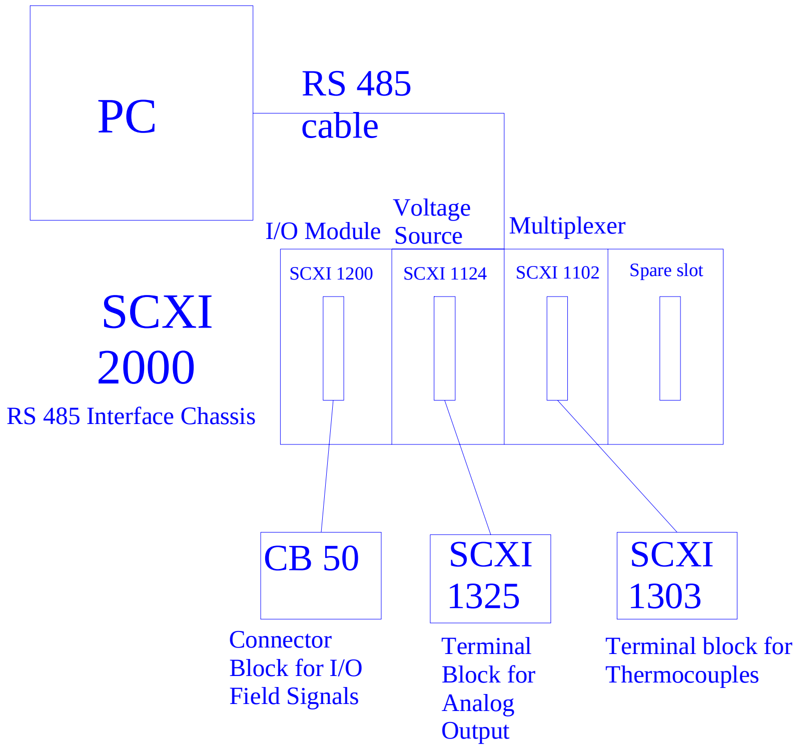

Figure 2.
Block diagram for data acquisition system.

(iv) MET/EET program quality
(v) program services and facilities.

B. Employer survey
C. Mathematics background assessment
D. Homework, quizzes and tests
E. Laboratory assignments and reports
F. Co-op/internship assessment report.

Based on these data Instrumentation and control curriculum will be assessed annually and fine tuned to maximize objectives.

7. Time line for completion of the project

Curriculum development for the EET 2500 course was completed in July 1998. Laboratory development is scheduled to be completed by June 2000. Though the new course is gradually introduced from fall 1998, student will be able to use the new laboratory from fall 2000. Noncredit courses for industry training will start after first cycle of evaluation of this project. Since student outcomes assessment data is collected annually, First set of assessment data will be available for analysis in June 2001.

8. Conclusion

The idea of modular curriculum, flexibility based on student background and outcomes assessment together is used in this course development for the first time. After full implementation of this new curriculum, student learning is expected to enhance significantly compared to old curriculum. Advisory committee of both MET and EET programs enthusiastically approved the new course. We expect enrollment in the course to increase from fall 2000. If this succeeds, similar approach will be used to update other courses in the engineering technology department. This type of model can be easily customized and adopted by different engineering technology programs of peer institutions, especially those with diverse student body. Similar pattern can also be adopted by four-year mechanical and electrical technology programs to upgrade existing instrumentation and control courses.

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Appendix

Instrumentation and control curriculum modules

Module (a) Modern industrial process:
Lecture: Introduction to industrial processes, examples, block diagram, process characteristics, process variables, units, measurement and process control fundamentals. (4 hours)
Lab: Study of pressure, flow, level and temperature processes. (6 hours)

Module (b) Sensors and transducers.
Lecture: Characteristics of instruments, sensors (elastic, thermal, motion, gravity, capacitive, resistive, inductive, piezoelectric, semiconductor, radiation and optical), instruments and transducers for pressure, temperature, thermocouple, force, motion, power, flow, viscosity, level and humidity measurement. (8 hours)
Lab: Calibration of transducers, study of sensor characteristics and measurement of process variables. (12 hours)

Module (c) Data acquisition and data processing:
Lecture: Statistical significance of experimental data, analog and digital data, data conversion, signal conditioning, data acquisition hardware and programming. (6 hours)
Lab: Data acquisition system components, LabVIEW programming for data sampling, input and output data processing. (6 hours)

Module (d) Process control:
Lecture: Process control elements- control valves, actuator, open & closed loop control, servomechanism and mode of control. (6 hours)
Lab: Pressure, temperature, flow level and speed control, LabVIEW programming for process control. (6 hours)

Module (e) Integrated measurement, data acquisition and control:
Lecture: Industrial process, transducer, measurement, data acquisition and process control. (6 hours)
Lab: Multivariable process control and cascade control loop. (9 hours)