AC 2012-3290: M.S. IN ENGINEERING TECHNOLOGY: EXAMPLES FROM CONTROL SYSTEMS

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MS in Engineering Technology: Examples from Control Systems

Abstract

In the decades following the 1955 Grinter report, over 96 U.S. institutions have developed TAC/ABET B.S. degrees in Engineering Technology (ETEC), with at least 50 sustaining enrollments of 200+ students in fall 2010 according to ASEE data. On the other hand, since the 1980's only about 14 institutions have created master's degrees in ETEC. Some M.S. programs have evolved from Master of Science in Technology (M.S.T.) or Master of Technology (M.T.) versions. One fundamental question posed in the debate is whether ETEC curricula rise to the necessary scientific rigor of traditional M.S. degrees. This paper asserts that the M.S. in ETEC should stand on equal footing with M.S. programs in any other field and particularly in engineering when viewed from the perspective of (i) the scientific level of graduate ETEC courses; (ii) the roles that ETEC graduates perform in the engineering profession; and (iii) the philosophy of research in ETEC. Although examples may be drawn from any ETEC area, the presentation centers around the requirements of an M.S. in ETEC – Systems Control Technology using a graduate level course in modern control systems to discuss pre-requisites, mathematics depth, the typical requirements and specifications language used in the design of a modern control system, the tools and techniques needed to solve the problem, and the fulfilled expectations regarding the philosophy of research in ETEC. Two recent Project and Thesis examples in the SCT track are also highlighted to illustrate program results. Ultimately, ETEC programs at the undergraduate and graduate levels continue to play a critical role in increasing the number of qualified professionals entering the engineering profession.

Introduction

The objective of the Committee on Evaluation of Engineering Education leading to the 1955 Grinter report was to provide students a choice between scientifically-oriented and pragmatic, hands-on-oriented curricula. Although the majority of engineering faculties were unable to agree in 1955 with the concept of "*bifurcation of engineering curricula*", the Committee's objective was achieved [1, 2]. The Grinter report coupled with the 1957 Sputnik launch are seen as a transformational cornerstone prompting U.S. engineering (ENG) curricula to embrace a much heavier prescription of mathematics and science. The transformation gradually led to an increase in lecture hours in upper division engineering courses richer in theory but with less room for laboratory practice [3]. More recently and paradoxically, engineering departments have been pressured to reduce the total number of required credit hours in a 4-year B.S. degree plan while simultaneously increasing the acquisition of business-related skills. For at least the past 20 years, engineering programs have also seen the need to address attrition and keep their majors engaged via freshman courses that are hands-on, laboratory-oriented, and fun.

The events of the 1950's also set the stage for the proliferation of Engineering Technology (ETEC) programs as 2-year Associate's and as 4-year BTEC and B.S. degrees. In fact, over 60 colleges were offering 4-year ETEC degrees by 1965. Fast-forward to the most recent ASEE U.S. College Profile in June 2011 to find 96 institutions offering ETEC degrees and participating in the annual ASEE surveys. In fall 2010, there were 25,714 enrolled majors, 50 of the 96 institutions sustained 200+ students, and 5,863 students received the bachelor's degree.

Some programs are in a College or School of Engineering, for example, the College of Engineering at the University of North Texas and the Milwaukee School of Engineering; others are in separate units, such as the College of Technology at the University of Houston and at Purdue University; yet others exist without engineering programs on campus, such as the Southeastern Louisiana University. Some Universities continue to offer 2-year and 4-year ETEC degrees with seamless articulations such as Ferris State University. Unfortunately, others are phasing out ETEC programs and even whole departments – for example the College of Engineering and Applied Science at the University of Cincinnati and the College of Engineering at the University of Central Florida, respectively.

Despite the lower enrollment numbers in ETEC when compared to ENG now as it was in 1955, it is rather clear that ETEC programs play a critical role in the production of capable engineering professionals that are readily absorbed by technical industries. Simply consider the frequent news in 2011 describing the urgent need to curb job outsourcing and the subsequent decline in national manufacturing capacity; the increased reliance of our society on service industries responsible for over 70% of the monthly paychecks in the U.S.; the shortage of engineering professionals; the impending reduction in the engineering workforce due to retiring baby-boomers; and the profound difficulties in attracting the so-called millennial student to STEM career choices.

There continues to be misconception, miscommunication, and confusion regarding ETEC and its relation to ENG programs and to engineering as a career. The fact that 2-year Associate's programs are also called Engineering Technology adds to the confusion faced by students, counselors, parents, and many industry recruiters. One way to place ETEC and ENG programs and their graduates within the engineering profession has been suggested [4] that adopts MIT's Aeronautical Engineering Department CDIO model (http://www.cdio.org/) – Conceive, Design, Implement & Operate. CDIO can be used to describe a horizontal spectrum of engineering tasks that require distinct skills sets. When CDIO is adapted to ETEC and ENG educational programs, it is found to fit the fact that the majority of ETEC and ENG graduates gravitate to the middle of the range – Design/Implement – called to execute the functional engineering tasks of design, re-design, performance analysis & testing, translational research, and emerging technology implementation [5]. A very small percentage of these graduates go on to the "Conceive" side of the spectrum, normally requiring further academic work leading to advanced degrees (Ph.D. or M.S.); an equally small percentage of graduates work in the "Operate" side of CDIO, which probably attracts a larger percentage of graduates from 2-year programs. Efforts continue to be reported to identify ways by which ETEC and ENG programs can be mutually beneficial academically and for the profession [6, 7, 8]. The focus of these and future discussions should be on the engineering profession, that is, 3-5 years after graduation. Therefore, it is quite fitting to quote the following observation [9]: "The degree is Engineering Technology. The career is engineering."

The 1980's witnessed a debate on the need for master's degrees in ETEC [10, 11]. The controversy is believed to stem from the perception – still brought up today – that ETEC programs lack the scientific rigor and sophistication of other similar fields, primarily in engineering and science. Over the years, M.S. programs in ETEC have been established but as of fall 2009, only the 14 institutions in Table 1 reported to ASEE graduate ETEC enrollment numbers and degrees awarded totaling 1,015 and 219, respectively.

Table 1 Graduate ETEC Enrollments and Degrees Awarded, Fall 2009

Source: ASEE 2009 Edition Profiles of Engineering & Engineering Technology Colleges

Institution	**Master's Enrollment**	**Degrees Awarded**
Purdue University - College of Technology (IN)	317	55
Purdue University, Calumet - School of Technology (IN)	116	11
University of Houston - College of Technology (TX)	108	20
Rochester Institute of Technology - College of Applied Science and Technology (NY)	107	22
Indiana University-Purdue University Indianapolis - Purdue School of Engineering & Technology (IN)	101	25
Arizona State University at the Polytechnic Campus (AZ)	81	17
University of North Texas – College of Engineering (TX)	44	13
Southern Polytechnic State University - School of Engineering Technology and Management (GA)	30	15
Indiana University-Purdue University Fort Wayne - College of Engineering, Technology, and Computer Science (IN)	26	--
Brigham Young University – Fulton College of Engineering & Technology (UT)	25	6
Wayne State University – College of Engineering (MI)	24	17
Oregon Institute of Technology (Various Campuses) (OR)	20	7
The University of Memphis – Herff College of Engineering (TN)	9	7
Totals	**1,015**	**219**

Despite these low graduate-level numbers, it is expected that more M.S. programs in ETEC will be created in the future because of three main factors: there are over 100 B.S. programs in ETEC in the U.S.; graduate education is in demand; and ETEC faculty profile has changed drastically in the last decade to a majority of individuals holding a Ph.D. and being required to be heavily engaged in research and scholarly work needed to navigate the expectations of tenure and promotion.

This article describes the culmination of a series of efforts to offer an M.S. in Engineering Technology – Systems Control Technology track that balances technical courses and business-related courses coveted by industry. The work was done over a seven-year period (2004-2011) while the first author was on the faculty of the Department of Engineering Technology at the University of Houston. First, two separate Master of Technology programs were merged in 2005-06 to feature a set of core courses and two tracks. Then, in 2010 the degree was renamed Master of Science and the department introduced two new specializations in Mechanical Engineering Technology and in Systems Control Technology. The program seeks to prepare individuals with advanced technical competencies, capable of engaging in translational research applications, and who also have opportunities to develop a basic level of business skills related to project management, business planning, technology forecasting, entrepreneurship, organizational leadership, logistics, communication, and human resources.

As in other STEM programs, the students' learning outcomes are strongly correlated to their time commitment to the program. The principal factor impeding ETEC students from a full-time commitment to their education is the fact that many if not most are working professionals seeking a graduate degree several years after completing the B.S. As expected, we have experienced less than acceptable performance from many students who attempt to simultaneously juggle a graduate education with full-time jobs and other life commitments.

All else being equal though, we advocate that an M.S. in ETEC should stand on equal footing with the M.S. in any other field, particularly in ENG when viewed from the perspective of (i) the scientific level of graduate ETEC courses; (ii) the roles that ETEC graduates perform in the profession; and (iii) the philosophy of research in ETEC. We use a design example from a graduate level modern control course in the Systems Control Technology program, an M.S. Project, and an M.S. Thesis to highlight the technical content covered in class, the competencies that the course and hence the program strive to instill, the philosophy of research expectations, and results of the program.

MS ET – Systems Control Technology (SCT) Degree Plan

The SCT degree is offered through the Department of Engineering Technology in the College of Technology at the University of Houston. The track provides opportunities to acquire an advanced knowledge of an inter- and multi-disciplinary field concerning advanced mathematics, systems modeling & simulation, wireless instrumentation, computer networking, control engineering, and embedded digital architectures to monitor and shape the behavior of systems. “Systems” refers to a natural or engineered relation between inputs and outputs that find applications in virtually all engineering fields. Graduates are prepared to work as advanced level control technologists in a wide range of industries including manufacturing, automation & robotics, energy, automotive, aerospace, and process control.

The SCT track complements those in Network Communications and in Mechanical Engineering Technology and share a common technical core in project management and in advanced mathematics. The core control curriculum in the SCT track enables students to master established system simulation and control technology implementation using classical and modern design and analysis techniques. Elective courses are offered in complementary fields so that students select an industrial application of interest. Other electives may be chosen from an industry-skills set to sharpen business-related competencies. The program includes a master’s thesis or a master’s project option. Table A-1 in Appendix A lists a recommended sequence of courses to complete the program in four semesters:

- **Semester 1**: the seminar serves to introduce new students to university and college facilities and resources, general faculty research interests, thesis/project requirements and document formatting, and the responsible conduct of research. Other courses deal with mathematics background, classical controls, and fundamentals of project management.
- **Semester 2**: modern and digital control techniques are core in this program. The electives listed in Table A-2 of Appendix A provide options from a technical list or an

industry-skills list. Technical courses offer a variety of choices in network communications, mechanical engineering technology, and controls. Students are encouraged to take a set of electives that fit their research interests and their background. The industry-skills courses are intended to develop business-type competencies. Students are encouraged to select a set consistent with their interests.

- **Semesters 3 and 4**: students complete the set of electives and a Project (one semester) or Thesis (2 semesters).

Pre-requisites, Competencies, Expectations, and Research

In our view, *research in ETEC entails the systematic application of advanced science, engineering, and mathematics to synthesize an implementable solution to a problem of industrial relevance using known or emerging technology.* Here "technology" is loosely used to include appropriate *hardware* specific to an engineering discipline; any *software* tool such as CAD/CAE; or an abstract design *technique* or an *algorithm* described in a textbook, a patent, or any other scholarly publication. Therefore, research in ETEC is naturally translational, applied, and led primarily by short- and medium-term industry needs.

It is widely understood that ENG curricula tend to prepare its graduates to accept responsibilities closer to the "design" and even "conceive" functions of CDIO. By necessity, ENG students are required to undertake mathematics courses beyond calculus, science courses that are based on differential and integral calculus, and core engineering courses that demonstrate the utilization of such math and science in system level design situations. By contrast, ETEC curricula prepare its graduates to accept responsibilities closer to the "implement" and even "operate" functions, which require a different focus, different interest, and indeed a different skill-set from abstractions and complex mathematical manipulations. One valid question then is what happens at the graduate level in ETEC and what are the research expectations?

Experience shows that the majority of B.S. ETEC graduates need a course dealing with engineering applications of mathematics. Hence, we have found it necessary to require all students in the SCT program to take or have an equivalent credit for the course ELET6305 Analytical Methods in ET (Table A-1, Appendix A). This course covers a wide range of applications of various subjects including dynamical modeling and differential equations, sampling, difference equations, transfer functions, state-space modeling, and the use of Laplace and Z Transforms in that context; in addition, the course covers selected topics in linear algebra such as eigenvalue/eigenvectors, matrix exponentials, similarity transformations, linearization, and applications to solving differential and difference equations. The course (or equivalent) is also required in the Mechanical Engineering Technology program, and is deemed critical in ensuring that students have fundamental mathematics skills to continue with control-specific courses.

The core control classes are ELET 6340, 6304, and 6342 (Table A-1, Appendix A). The majority of B.S. ETEC graduates will not have taken an introductory controls class. The course ELET6340 Electro-Mechanical Systems Control fills this pre-requisite void by covering modeling, analysis and design of single-input single-output (SISO) transfer functions describing typical electromechanical systems under feedback control using primarily Root Locus techniques leading to a PID design and analysis. Note that ELET6305 and 6340 may be taken concurrently which we have found to be beneficial. These courses are followed by ELET 6304 covering classical and modern control topics primarily in the discrete-time domain. The first half of ELET 6304 is a close follow-on course to ELET 6340; the second half uses state-variables and modern control. ELET 6342 is based exclusively on state-space (modern) approaches and covers full-state feedback, observers, and fundamentals of optimal control via the Linear-Quadratic Regulator framework. The four courses just described round up a set of topics that are critical for students to be able to read further control literature and select applications of theory for their research.

The scope of the problem and the depth or breath of the STEM knowledge and tools needed in the solution will typically determine whether the research leads to a Project or to a Thesis. If the research component leads to a Project, the approach will be led by well-established technologies and STEM knowledge and tools as applied to an industry-relevant problem that has a broader scope than that of a typical end-of-course project. The Project is normally completed in one semester, and is the equivalent of taking one 3-credit graduate course requiring 13-15 hours per week. A written, formal technical report is expected that describes the problem, and communicates the approach and the results followed by a formal presentation.

On the other hand, if the research component leads to a Thesis, the approach will be led by an innovation to existing technology or by translational research via the application of emerging technology, which may need a more advanced utilization of STEM knowledge and tools. The Thesis is normally completed in two semesters, and is the equivalent of taking 6-credits of graduate courses requiring 13-15 hours per week. A written, formal Thesis is expected that describes the innovation or the emergent technology and the results, followed by a formal defense to a faculty committee. Very often, the Thesis also results in a refereed publication in an appropriate venue. Ideally, the Thesis Committee will include at least one member from industry.

Examples

This section contains three examples. First, a typical Course-level problem is used to illustrate the expected level of sophistication in a graduate ETEC course in the second year of the SCT track. In particular, this example shows the mathematics breadth, the typical requirements and specifications language used in the design of a modern control system, and the tools and techniques needed to solve the problem. The presentation here follows how it would be discussed in class with various details omitted for brevity. It is also important to note that although the level of mathematics is sophisticated, students in ETEC are primarily required to master the use of the indicated techniques while de-emphasizing any theoretical derivations and proofs. The second and third examples show recent (Fall 2011) Project-level and Thesis-level contributions to satisfy the requirements of the M.S.

Course-level example. The schematic of a crane (trolley) with a hanging load (payload) is shown in Figure 1 with associated equations of motion given by a pair of nonlinear differential equations (1-2)

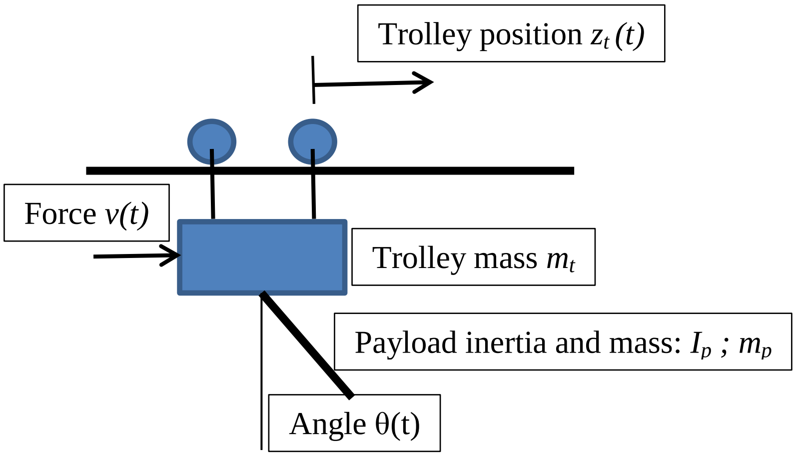


Figure 1. Schematic of a Crane and Payload

$$\left(I_p + m_p L^2\right)\ddot{\theta} + m_p g L sin(\theta) + m_p L cos(\theta)\ddot{z}_t = 0 \qquad (1)$$

$$\left(m_t + m_p\right)\ddot{z}_t + \beta\dot{z}_t + \left[m_p L cos(\theta)\right]\ddot{\theta} - \left[m_p L sin(\theta)\right]\dot{\theta}^2 = v(t) \qquad (2)$$

Letting the 4-dimensional state vector *z(t)* consist of the payload angle, its speed, the trolley position, and its speed, the above equations may be rewritten in vector form as follows

$$\dot{z} = F(z, v) \qquad (3)$$

suitable to compute linearized models. In this problem, an equilibrium point denoted by a superscript (*) is obtained by setting equation (3) to zero resulting in $\left[\theta^*, \dot{\theta}^*, z_t^*, \dot{z}_t^*, v^*\right] = [0, 0, z_t^*, 0, 0]$ which corresponds to a stationary payload and crane with no externally applied forces. Therefore, the linear model valid in the vicinity of this equilibrium is the 4-dimensional system

$$\dot{x}(t) = \left[\frac{\partial F}{\partial z}\right]_{(*)} x(t) + \left[\frac{\partial F}{\partial v}\right]_{(*)} u(t) = Ax(t) + bu(t)$$

$$(4)$$

$$y(t) = C'x(t)$$

where the pair $[x(t), u(t)]$ represents small deviations about the equilibrium (*), and *y(t)* is an output (or vector of outputs). In order to simplify the calculations considerably, we may use the approximations

$$\sin(\theta) \sim \theta; \quad \cos(\theta) \sim 1; \quad \sin(\theta)\,\dot{\theta}^2 \sim 0; \quad \beta \sim 0$$

in equations (1-2) directly which lead to the nominal transfer function (plant) from payload angle to applied force given by

$$\frac{\Theta(s)}{U(s)} = \frac{b_0}{s^2 + a_0}; \quad where \quad a_0 = \frac{(m_t + m_p)m_p gL}{(I_p + m_p L^2)(m_t + m_p) - {m_p}^2 L^2}$$

$$and\ b_0 = \frac{-m_p L}{(I_p + m_p L^2)(m_t + m_p) - {m_p}^2 L^2}$$

The course ELET6304 “Applied Digital Control Systems” would continue with a discussion on sampling frequency selection based on the system’s natural frequency of oscillations, the discretization of the plant, the effect of sampling period on the plant’s poles and zeros, and simulations of control designs in cascade (e.g., PID using Root Locus) and in full-state feedback configurations using pole placement formulas. In the course ELET 6342 “Modern Control Systems Applications”, the discussion would instead move to the use of the Linear-Quadratic Regulator (LQR) formulation to design optimal controllers. For example, using equation (4) a meta-state *q(t)* is assembled and found to satisfy the system of equations

$$q(t) = \begin{bmatrix} \dot{x}(t) \\ e(t) = \mathrm{y(t)} - \mathrm{y_r} \end{bmatrix} \Rightarrow \dot{q}(t) = \begin{bmatrix} A & 0 \\ C' & 0 \end{bmatrix} q + \begin{bmatrix} b \\ 0 \end{bmatrix} \dot{u} \qquad (5)$$

where *e(t)* is an error signal between the plant output and a reference output $\mathrm{e(t)} \equiv \mathrm{y(t)} - \mathrm{y_r}$. In this formulation, a control *u(t)* is sought to minimize the quadratic cost

$$\mathrm{J} = \int_0^\infty (\mathrm{q'Qq} + \dot{\mathrm{u}}'\mathrm{R}\dot{\mathrm{u}})\, \mathrm{dt}$$

that weighs a measure of state deviations from zero and energy expenditure. Under an easy to check controllability condition, the optimal solution is known to be full-state feedback leading to

$$u(t) = -K_P x(t) - K_I \int e(t)\, dt \qquad (6)$$

where the constant gains K_P and K_I are given by $[K_P \;\; K_I] = R^{-1}b'P$ and matrix P is the unique positive-definite solution of the steady-state Riccati equation

$$A'P + PA - PbR^{-1}b'P + Q = 0$$

Assuming that only the payload speed (or the angle) is measurable, the final step is to design a linear observer that estimates the payload angle (or the speed). The design and analysis are done in the Matlab/Simulink environment.

Project-level example: Control of a Distillation Column [12]

Nearly 40% of the energy consumed in the chemical and refining industries is used by distillation processes. Thus, worthwhile industrial objectives include understanding the behavior of distillation processes, predicting their response under a wide range of operating conditions, and operating them under reduced energy consumption conditions while making products of desired quality. This project was concerned with the modeling, simulation, and control of heat integrated distillation columns. The widely used industrial separation of benzene, toluene, and m-xylene was considered as a case study. The impact of heat integration was analyzed from an energy savings viewpoint. Heat integrated distillation columns are generally more complicated from a control viewpoint because of the greater degree of interaction among the columns. Thus, different control structures, ranging from feedback only to more sophisticated ones such as feed forward and cascade, and tuning methods are devised and compared from a performance viewpoint when product composition set-point changes or feed rate and feed composition disturbances are introduced. Furthermore, extensive use of Aspen Engineering tools was made to facilitate project execution. AspenPlus was used for steady state simulation and Aspen Dynamics was used for dynamic model development and control structure evaluation. These tools are exactly the same used by major industries for the design, optimization and retrofitting of important processes.

From a learning point of view, this project requires a sound technical background encompassing several disciplines, namely: unit operations, steady state and dynamic modeling, industrial modeling and simulation tools, and process control. Key results shown below demonstrate the breadth and depth of the required technical knowledge. The separation of benzene, toluene, and m-xylene was also studied by Cheng and Luyben [13] from a steady state point of view. Initially, it was verified that the original case 8 of the Cheng/Luyben study was the least energy consuming heat integrated column arrangement. AspenPlus was used to perform the steady state analysis and process arrangement selection of the configuration shown in Figure 2.

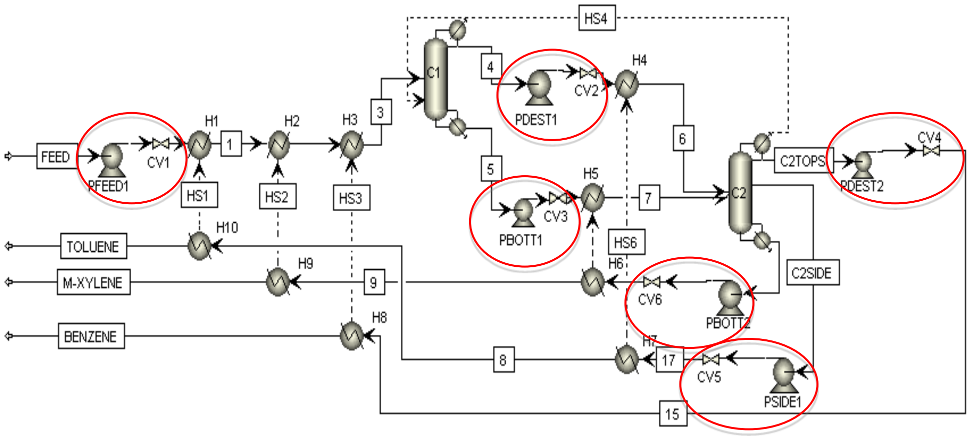
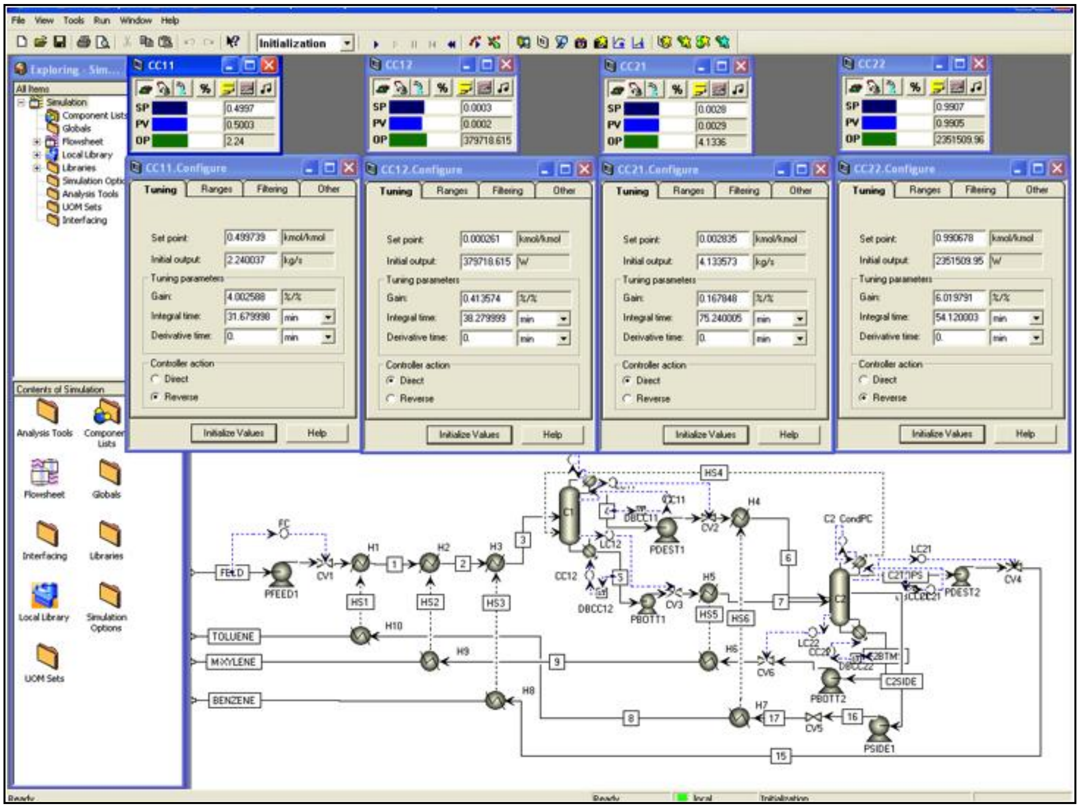


Figure 1: Case-8 Process Configuration in Aspen Plus

Using this steady state design, the project developed a rigorous dynamic process simulation using Aspen Dynamics. Figure 3 shows a snapshot of the dynamic process simulator along with basic controllers for material balance and proportional/integral (PI) controllers for product composition control. Empirical models were developed using data gathered from the dynamic simulation by perturbing the manipulated variables (e.g. reflux, heat input) in a stepwise manner. These empirical models were first order or second order plus time delay models. A typical model which relates the reflux to the benzene composition of the distillate product of the first column is given below, along with its equivalent using a Pade approximation:

$$G_{R1D1}(s) = 0.1291\frac{e^{-36s}}{828s+1} = -1.559\times10^{-4}\frac{(s-0.0556)}{(s+1.208\times10^{-3})(s+0.0556)}$$



CC11

SP 0.4997
PV 0.5003
OP 2.24

CC11.Configure

Set point: 0.499739 kmol/kmol
Initial output: 2.240037 kg/s
Tuning parameters
Gain: 4.002588 %/%
Integral time: 31.679998 min
Derivative time: 0. min
Controller action
○ Direct
● Reverse

CC12

SP 0.0003
PV 0.0002
OP 379718.615

CC12.Configure

Set point: 0.000261 kmol/kmol
Initial output: 379718.615 W
Tuning parameters
Gain: 0.413574 %/%
Integral time: 38.279999 min
Derivative time: 0. min
Controller action
● Direct
○ Reverse

CC21

SP 0.0028
PV 0.0029
OP 4.1336

CC21.Configure

Set point: 0.002835 kmol/kmol
Initial output: 4.133573 kg/s
Tuning parameters
Gain: 0.167848 %/%
Integral time: 75.240005 min
Derivative time: 0. min
Controller action
● Direct
○ Reverse

CC22

SP 0.9907
PV 0.9905
OP 2351509.96

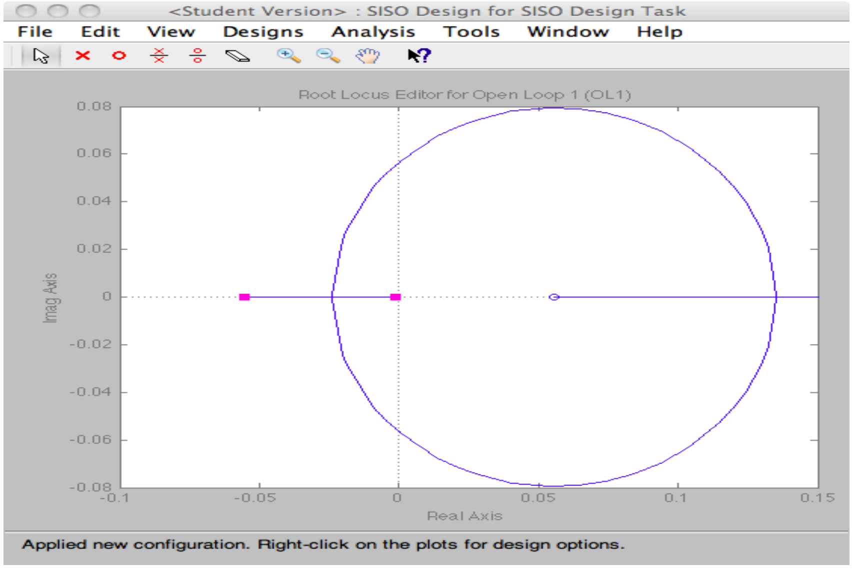
CC22.Configure

Set point: 0.990678 kmol/kmol
Initial output: 2351509.95 W
Tuning parameters
Gain: 6.019791 %/%
Integral time: 54.120003 min
Derivative time: 0. min
Controller action
○ Direct
● Reverse

Figure 3: Dynamic Simulation and Product Composition Control

The MATLAB® software is used for controller design. The methodology is based on the Root Locus technique and using SISOTOOL. Figure 4 shows the root locus for the transfer function GR1D1(s) while Figure 5 shows the closed loop system response to a set-point change for benzene in the distillate product when the PI controller is:

$$G_{CR1D1}(s) = 0.0470\frac{(1+2x10^{3}s)}{s}$$



Applied new configuration. Right-click on the plots for design options.

Figure 4: Root Locus for GR1D1(s)

Figure 5: Step response of the system GR1D1(s) in the presence of a PI controller

Thesis-level example: Control of a defibrillator [14]

Sudden cardiac death is one of the primary causes of death in the US and several other developed countries; however, cardiac arrest is reversible in most victims if it is promptly treated. The most effective method of addressing ventricular fibrillation is through an electrical shock produced by Automated External Defibrillators (AED). The literature is rich in defibrillation studies applied to electrical models of the heart represented by a single resistorcapacitor (RC) circuit. A bi-domain model given by a pair of nonlinear partial differential equations has been used extensively to graph the complex and distributed nature of the electrical activities of the heart [15], and was shown to produce an infinite network of RC-circuits [16].

A hypothesis is formulated whereby certain mechanical features of a fibrillating heart treated as an expanding and contracting volume may be found to be analogous to those present in electrical signals obtained from EKG tests. Hence, for the first time to the best of our knowledge, an electro-mechanical model shown in Figure 4 based on the operation of a simple translational DC motor is proposed to capture key features of a fibrillating heart. The mechanical model is a mass/spring/damper system; the gain K_f converts electrical current I_h to force f; the current I_{sa} is the naturally occurring synchronization signal produced by the heart's sinoatrial node responsible for the normal electrical waves in the cardiac muscle which leads to the mechanical pumping action and heartbeat; I_c is the control current generated by the AED; and the output $y(t)$ is the speed of the contracting/expanding mass.

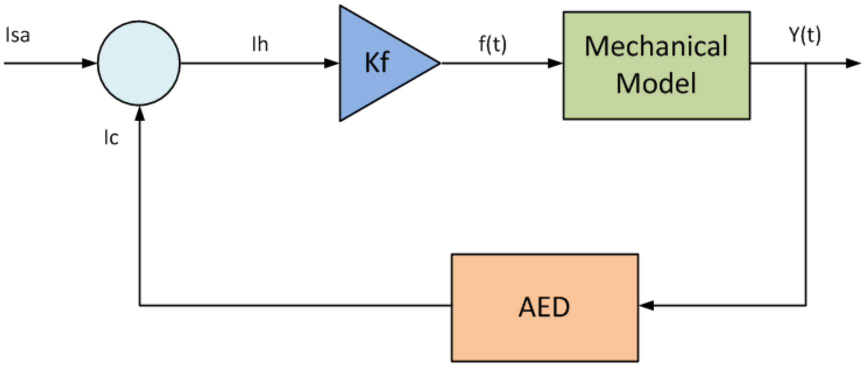


Figure 4. Electro-Mechanical Model of a Heart and External Defibrillator

An optimal defibrillating controller of the form given in equation (6) is designed and shown to produce acceptable results in simulations for both electrical (RC circuits) and electro-mechanical models (Figure 4). Figure 5 illustrates the speed of the heart under the action of the AED signal while fibrillating. The fibrillating effect is simulated by setting I_{sa} as a zero mean Gaussian signal.

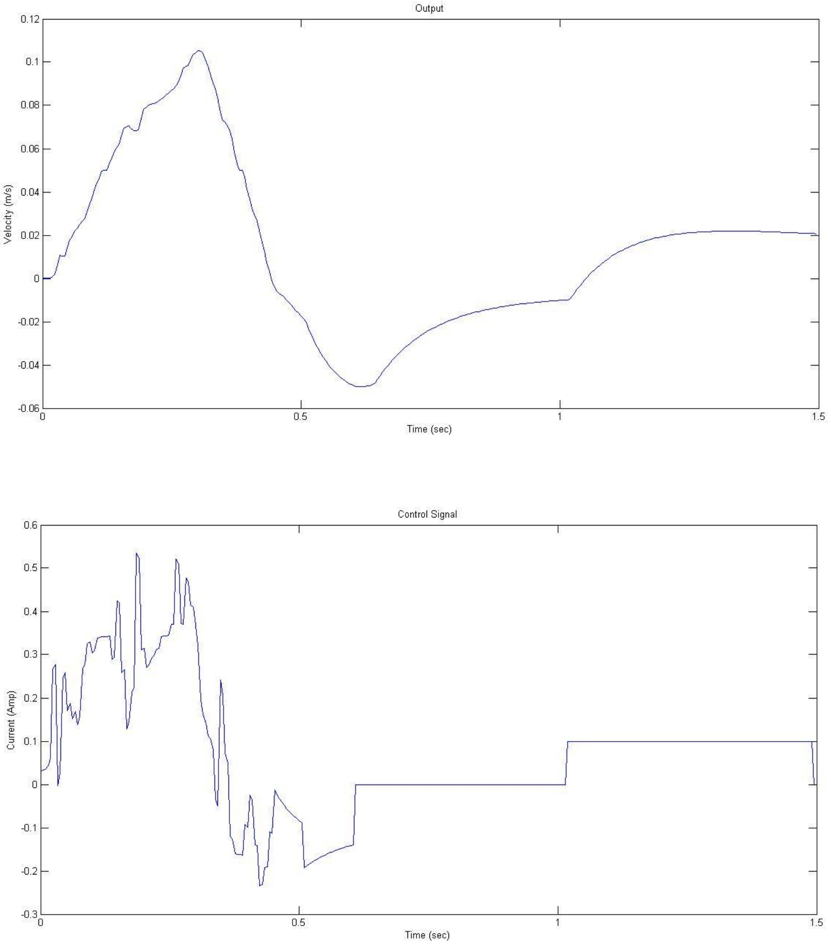


Figure 5. (Top) Speed of the Electromechanical Model Under De-fibrillation ($t \leq 0.5$ *sec*) and Under Normal Action by the Sinoatrial Node ($t \geq 0.5$ *sec*). (Bottom) Control Signal Generated by the AED

Conclusions

As of fall 2009, only 14 institutions in the US offer M.S. degrees in Engineering Technology (ETEC). However, given that there are over 100 B.S. programs in ETEC, that graduate education is in demand, and that the ETEC faculty profile has changed considerably in the last decade, it may be predicted that many more M.S. in ETEC programs will spring up in the near future. An existing M.S. in Systems Control Technology is offered as an example that can be made to grow in enrollment, in faculty interaction with industry, and in research productivity. Similar programs in other institutions may be viable only if they are built to test the expected scientific rigor of the M.S.

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Appendix A. SCT Course Sequence & Description

Table A-1 Recommended Course Sequence – SCT Program

Semester 1		**10 Hours**
	ELET6100^ Seminar	1
	ELET 6305***** Analytical Methods in ET	3
	ELET 6340***** Electro Mechanical Systems Control	3
	TEPM 6301* Project Management Principles	3
Semester 2		**9 Hours**
	ELET 6304^ Applied Digital Control Systems	3
	ELET 6342^ Modern Control Systems Applications	3
	ELECTIVE**	3
Semester 3		**9 Hours**
	ELECTIVE**	3
	ELECTIVE**	3
	Thesis Option ELET 6399^	3
	Project Option ELET6396^ OR ELECTIVE**	
Semester 4		**3 or 6 Hours**
	Thesis Option ELET 6399^	3
	Project Option ELET6396^ OR ELECTIVE** Project Option ELECTIVE**	6
Total		**31 OR 34 Hours**

^	Required course for Thesis or Project options
*	May be substituted by ELECTIVE** if student demonstrates having equivalent background
**	ELECTIVE courses from pre-approved Technical or Industry-Skills list. Thesis Option degree plan must include at least one elective from the Technical list.

Table A-2 Technical and Industry-Skills Courses – SCT Program

Technical Courses	Industry-Skills Courses
ELET 6301: Applied Digital Signal Processing	LOGT 6314: Measurement and Evaluation of Supply Chain Operations
ELET 6303: Applied Neural Networks	LOGT 6316: Global Supply Chain Operation
ELET 6325: Practicum in ET	LOGT 6318: Supply Chain Strategies
ELET 6332: Physiological Systems Mod. & Sim.	LOGT 6320: Procurement Strategies
ELET 6348: Power Systems Control Technology	TEPM 6302: Leadership and Team Building
ELET 6315: Sensor Networks	TEPM 6303: Risk Assessment in Proj. Mgmt.
ELET 6302: Advanced Wireless Networks	TEPM 6304: Quality Improvement in Proj. Mgmt.
ELET 6313: Network Security	HRD 6301: Global Leadership in Training
MECT 6310: Instrumentation and Measurement	HRD 6303: Assessment and Evaluation in HRD
MECT 6332: Fundamentals of Drilling Technology	HRD 6305: Org. Learning and Performance
MECT 6342: Thermal Processing and Post-Processing of Materials	HRD 6356: Consulting and Professional Practice
MECT 6381: Applications in Systems Eng. I	TECH 6311: Introduction to Future Studies
MECT 6382: Applications in Systems Eng. II	**College of Business** Consult an adviser