Session 3533

Improvements in Electric Power Systems Curricula: Developing Continuous Improvement Plan

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Faculty at three universities in the New York / Pennsylvania region offer their engineering technology students required or elective sequences in electric power systems. The three institutions were each looking at possible changes to their respective courses to make them more relevant to the power systems industry which is struggling to assure reliable and economic delivery of power in the light of deregulation and the blackouts of the recent past.

The authors are looking at TC2K Criteria Elements, such as program educational objectives, program outcomes, assessment and evaluation, as well as program characteristics. All these components are compared between three universities. Methodology for continuous improvement is proposed based on the results of the study.

The four faculty compiled the results of the surveys and determined which input was most valuable to each university, comparing the various metrics which were available.

Materials Developed for TAC of ABET

Buffalo State College (BSC) and Rochester Institute of Technology (RIT) were both re-visited by TAC of ABET in the Fall of 2004. Their materials are included from those used in the self-study process for their first TC2K visit. The University of Pittsburgh at Johnstown (UPJ) has not yet been visited since TC2K has been in force. Their materials are based on their internal continuous improvement process.

Program Educational Objectives (PEO's)

The TAC of ABET defines these as very general objectives which alumni should have achieved after a few years of employment in industry. The following is a summary of the PEO's, which the EET programs at each of the three universities have included:

Program Educational Objective	Buffalo State College	Rochester Institute of Technology	University of Pittsburgh at Johnstown
Attained employment in the field.	Yes	Yes	Yes
Pursued Additional Formal Education and / or certification	Not as such.	Yes	Stated as offering opportunities at UPJ – "lifelong learning process"
Attained increasing levels of responsibility and leadership in their	Professional Success	Yes	As part of a basic principle – "grow and develop"

chosen field.			
Ethical standards directed toward solving technological problems of industry and society.	Part of a PO, not a PEO	Part of a PO, not a PEO.	Yes
Human Relations Skills	Part of a PO, not a PEO	Part of a PO, not a PEO.	Yes
Measurements	Alumni and employer survey every six years	Several measurements in Alumni Survey done every 6 years.	Alumni and employer survey every six years.

Program Outcomes (PO's)

TAC of ABET defines a program outcome as an action which a student demonstrates upon graduation from an accredited program. TAC of ABET defines a set of program outcomes (a-k) which each program must obtain and a set of program criteria for each of the various programs. Each program can define its own program outcomes, so long as it maps them to the general (a-k) and specific program criteria. The following table is a quick summary of the program outcomes defined by the three universities.

ABET Definition	General Category	BSC	RIT	UPJ
		From ABET Self Study	From ABET Self Study	From Continuous Improvement Plan
a	Mastery of Knowledge in Technical Fields	Yes	Yes	Yes
b	Apply Knowledge in Technical Fields	Yes	Yes	
c	Experimentation	Yes	Yes	Yes
d	Creativity in design	Yes	Yes	
e	Work in Teams	Yes	Yes	Yes
f	Solve Technical Problems	Yes	Yes	
g	Communicate Effectively	Yes	Yes	Yes
h	Lifelong Learning	Yes	Yes	
i	Professional, Ethical and Social	Yes	Yes	Yes
j	Diversity and World Issues	Yes	Yes	Yes
k	Quality, timeliness, CIP	Yes	Yes	
Program Criteria	Circuits, programming, etc.	Yes	Yes	
"	Apply Physics / Chemistry	Yes	Yes	
"	Depth & Breadth	Yes	Yes	Yes
"	Various EET Fields	Yes	Yes	
"	Project Management	Yes	Yes	
"	Math beyond Calculus	Yes	Yes	
Institutional		N/A	N/A	

Note: Those categories which have not been checked in these tables are ones which UPJ has not specifically called out in their internal CIP process. They will be preparing for a TC2K visit in the near future.

Conclusions from PEO's and PO's:

It is obvious that each EET program has to meet ABET standards, and from the first two tables they have met these minimum standards for the programs.

There were not particular institutional PEO or PO statements which would alter individual programs or courses at the respective universities.

Specific Course Materials in Power Systems

Since this paper will focus particularly the power system required or elective courses, it is now time to look at the specifics of three sets of courses in power systems: electric machines, power systems and power electronics. In each case, there may be more than one course in a given area but we will lump the courses into these three categories.

In each of the three areas, there are also three items worth investigating. The first is what many who have written TAC of ABET self studies would call course outcomes or intended learning objectives. The second is the set of topics included in each area. The third is the laboratory exercises included (if any) in each course.

Part of the exercise of preparation for ABET is to be as specific as possible, without listing items that cannot or will not be measured. While some of the items are certainly included in a course, they are not stated because they are not going to be measured in the particular course at the particular institution. Where "Not stated" is used, the material may well be covered, but not measured for ABET purposes.

Electric Machines

Electric Machines Course Outcomes	BSC	RIT	UPJ
Identify types, characteristics and components	Yes	Not stated	Yes
Convert transformers and machines to circuit models	Not stated	Yes	Yes
Measure the electrical and mechanical parameters	Yes	Yes	Yes
Specify motors, generators and transformers	Yes	Yes	Yes
Work in teams to build, troubleshoot and analyze devices.	Not stated	Yes	Yes
Obtain / compare data to theory.	Yes	Yes	Yes
Compare electrical and mechanical quantities	Yes	Yes	Yes
Good written report	Yes	Not stated	Not stated
Technical Literacy and Lifelong Learning	Yes	Not stated	Not stated
Role and limitations of technology	Yes	Not stated	Yes

Electric Machines Topical Content	BSC	RIT	UPJ
Review of Circuits	Yes	Yes	Yes
Transformer Parameters and specifications	Yes	Yes	Yes
Ideal and realistic transformers	Yes	Yes	Yes
Transformer parameters referred to high side and low side.	Yes	Not stated	Yes
Rotating Magnetic Field	Yes	Yes	Yes
Induction Motor Principles	Yes	Yes	Yes
Squirrel Cage and Wound Rotor3 Phase Induction Motors	Yes	Yes	Yes
Single Phase Induction Motors	Yes	Yes	Yes
Speed and torque control of induction motors	Yes	Not stated	Yes
Solid State motor controls	Yes	No	Yes
Fractional HP motors, application and types	Yes	Yes	Yes
Stepper Motors & controls	Yes	Yes	No
Synchronous Motors and generators	Yes	Yes	Yes
Rotor Types	Yes	Yes	Yes
Power Factor Correction with SM	Yes	Not Stated	Yes
Synchronous Machine Power Angle	Yes	Yes	Yes
Efficiency	Yes	Yes	Yes
Industrial Applications: specifications – selecting, sizing.	Yes	Not Stated	Yes
DC Machines	Not Stated	Yes	Yes

Electric Machines Laboratory Topics	BSC	RIT	UPJ
3 Phase AC Circuits	Not stated	Yes	Yes
3 Phase Power & Phase Sequence	Not stated	Yes	Yes
Transformer, Motor & Generator Testing Procedures	Yes	Yes	Yes
Instrumentation for Testing	Yes	Yes	Yes
Simulation Software	Yes	Not Stated	Yes
Single Phase Transformer parameters and voltage regulation	Yes	Yes	Yes
Wound-Rotor induction motor	Yes	Yes	Yes
Squirrel cage induction motor	Yes	Yes	Yes
Synchronous Motor and Generator	Yes	Yes	Yes
DC machines	Not stated	Yes	Yes

Power Systems

Power Systems Course Outcomes	BSC	RIT	UPJ
Distinguish the elements of a power system.	Yes	Yes	Yes
Solve balanced and unbalanced 3 phase circuits	Yes	Yes	Yes
Solve power factor correction problems and apply various methods of controlling switched capacitors.	Yes	Yes	Yes
Find 60 Hz transmission line impedances	Yes	Yes	Yes
Apply various substation configurations, including placement of instrument transformers.	Implied	Yes	Yes
Determine the efficiency and voltage regulation of a transformer.	See Machines	Yes	Yes
Design and present the electrical layout of an industrial facility, city or region.	Industrial Facility	Yes	No
Apply basic criteria to troubleshoot for power quality	Yes	Yes	No
Write a paper on electric power systems, using significant references from technical magazines.	Yes	Yes	No
Solve a load flow for a power system.	Yes	Yes	Yes
Solve a simple economic operation problem with two generators.	No	Yes	Yes
Determine line fault currents using symmetrical components.	Yes	Yes	Yes
Use the equal area criterion to determine the stability of a power system.	Yes	Yes	No
Apply electromechanical and solid state relays to simple power systems.	Yes	Yes	Yes
Include concepts of supervisory control and telemetry in the study of power systems.	Implied	Yes	Yes
Do a class projects utilizing load flow, protective relaying and system faults.	Yes	Yes	Yes
Historical development of power systems to include effects of deregulation.	Yes	Implied	No
Per Unit Analysis	Yes	Implied	Yes
Simple Fault Analysis without symmetrical components.	Yes	No	Yes
Economics of Power Distribution	Yes	No	Yes
Lifelong learning skills.	Yes	Implied	Implied
Role and limitations of technology and need of responsible application of technology.	Yes	Implied	Implied
Demand Management and its calculations	Yes	No	No

Power Systems Topical Content	BSC	RIT	UPJ
Review of single phase power	No	Optional	No
Basic Elements of Power System	Yes	Yes	Yes
Balanced and unbalanced 3 Phase	Yes	Yes	Yes
Capacitors and PF Correction	Yes	Yes	Yes
Transmission Line configurations and impedances	Yes	Yes	Yes
Transformers, autotransformers and 3 phase transformers	Yes	Yes	Yes
Per Unit System, system parameters	Yes	Yes	Yes
Load management and energy conservation	Implied	Yes	Yes
Substation Layout	Yes	Yes	Yes
Metering and Instrument Transformers	Yes	Yes	Yes
Power Reliability and Quality	Yes	Yes	Yes
Class Project – Layout of a power system	Yes	Yes	Yes
Library project and oral presentation	Yes	Yes	No
Load flow – equations and simulation	Yes	Yes	Yes
Economic Operation – 2 Generators	No	Yes	Yes
Fault Analysis with symmetrical components	Yes	Yes	Yes
System stability – equal area criterion	Yes	Yes	No
System protection, using EM and SS relays	Yes	Yes	Yes
Supervisory Control and Telemetry	Yes	Yes	Yes
Capstone class project	Yes	Yes	No
Historic development of power systems to include effects of deregulation	Yes	Implied	No

Power Systems Laboratory Content	BSC	RIT	UPJ
30 degree phase shift in 3-phase transformers	Yes	Yes	Yes
Characteristics of Time Over-Current Relay	Not at this time	Not at this time (NATT)	Yes
Simulations of Faults and Load Flow	Yes	Yes	Yes
Characteristics of Directional Over-Current Relays	NATT	NATT	Yes
Characteristics of Differential Relays	NATT	NATT	Yes
Characteristics of Reverse Power Relays	NATT	NATT	Yes
Tour local power generation and industrial plant with large power systems in place	Yes	NATT	Yes
Use of Simulation Software: Power World Simulator, SKM Analysis	Yes	NATT	Yes
Protective Relay Coordination Studies	NATT	NATT	Yes

Note: Lab content is being revised at Buffalo State as a result of Schweitzer Engineering Laboratories equipment donation.

Power Electronics

Power Electronics Course Outcomes	BSC	RIT	UPJ
Describe the characteristics of power semiconductor devices	Yes	NATT	Yes
Demonstrate the principles of operation of static power conversion	Yes	NATT	Yes
Specify appropriate pulse-width modulation techniques for voltage and frequency control.	Yes	NATT	Yes
Select and design an appropriate technique of Thyristor commutation for an industrial application	Yes	NATT	Yes

Power Electronics Course Outcomes	BSC	RIT	UPJ
Relate the advantages and disadvantages of various conversion topologies.	Yes	NATT	Yes
Design a power electronics circuit for an industrial application.	Yes	NATT	Yes
Analyze the designs and apply design considerations for several power electronic circuits	Yes	NATT	Yes

Power Electronics Topical Content	BSC	RIT	UPJ
Applications of power electronics, and types of power electronic circuits	Yes	NATT	Yes
Characteristics of diodes and power semiconductor diodes	Yes	NATT	Yes
Diode Rectifiers: single and three phase rectifiers	Yes	NATT	Yes
Thyristors: Characteristics of silicon-controlled rectifiers, gate-turn-off thyristors and MOS-controlled thyristors	Yes	NATT	Yes
Controlled Rectifiers: Single phase converters and dual converters	Yes	NATT	Yes
AC Voltage Controllers: Single-phase and three-phase converters	Yes	NATT	Yes
Power Thyristors: Characteristics of power BJTs, MOSFETs and IGBTs	Yes	NATT	Yes
DC Choppers: step-down and step-up operation	Yes	NATT	Yes
Pulse-Width Modulated Inverters: Single-phase, three-phase inverters, voltage control of inverters, and current source inverters	Yes	NATT	Yes
Resonant-Pulse Inverters: Series-resonant and parallel-resonant inverters	Yes	NATT	No

Power Electronics Laboratory Content	BSC	RIT	UPJ
Diode characteristics	Yes	NATT	Yes
Diode rectifiers	Yes	NATT	Yes
Thyristor circuits	Yes	NATT	Yes
Thyristor controlled circuits	Yes	NATT	Yes
Single-phase converters	Yes	NATT	Yes
Three-phase converters	Yes	NATT	Yes
Single-phase inverters	Yes	NATT	Yes
Three-phase inverters	Yes	NATT	Yes

Continuous Improvement Model and Systems Approach

The authors utilized systems engineering principles [1] to the proposed model. These principles are:

- Decomposition and functional analysis
- Requirements or criteria
- Synthesis
- Testing
- Communications

Iterative top-down decomposition is utilized to the subject matter itself and results in topical outlines presented in the previous section. This process reflects actual engineering procedures and operations found in design and operations of electric power systems.

Requirements or criteria must be measurable, should be monitored throughout further steps of analysis, and could be optimized. Besides technical and economical requirements found in any engineering system the criteria specified in ABET Criterion 2 for program outcomes are also utilized.

With topical outlines known it is possible to propose an advanced curriculum based on interrelations between topics of different disciplines within Electrical Engineering Technology (EET) program, between EET and other programs, and between courses and programs in different institutions.

Communications are utilized through direct connections between blocks as well as feedback loops.

Figure 1 shows the diagram of proposed methodology.
The authors modified the process proposed in [2] by specifying the content of each block and adding additional feedback loop.
Program goals, program educational objectives, and suggestions from Industrial Advisory Boards are viewed as an intellectual input to continuous improvement program (CIP). Program outcomes are viewed as a process, while topical outlines are the output of the CIP and course outcomes are considered to be the outcomes of the CIP.
Conditions, such as faculty, facilities, equipment, institutional and external support, are treated as physical input to the CIP.

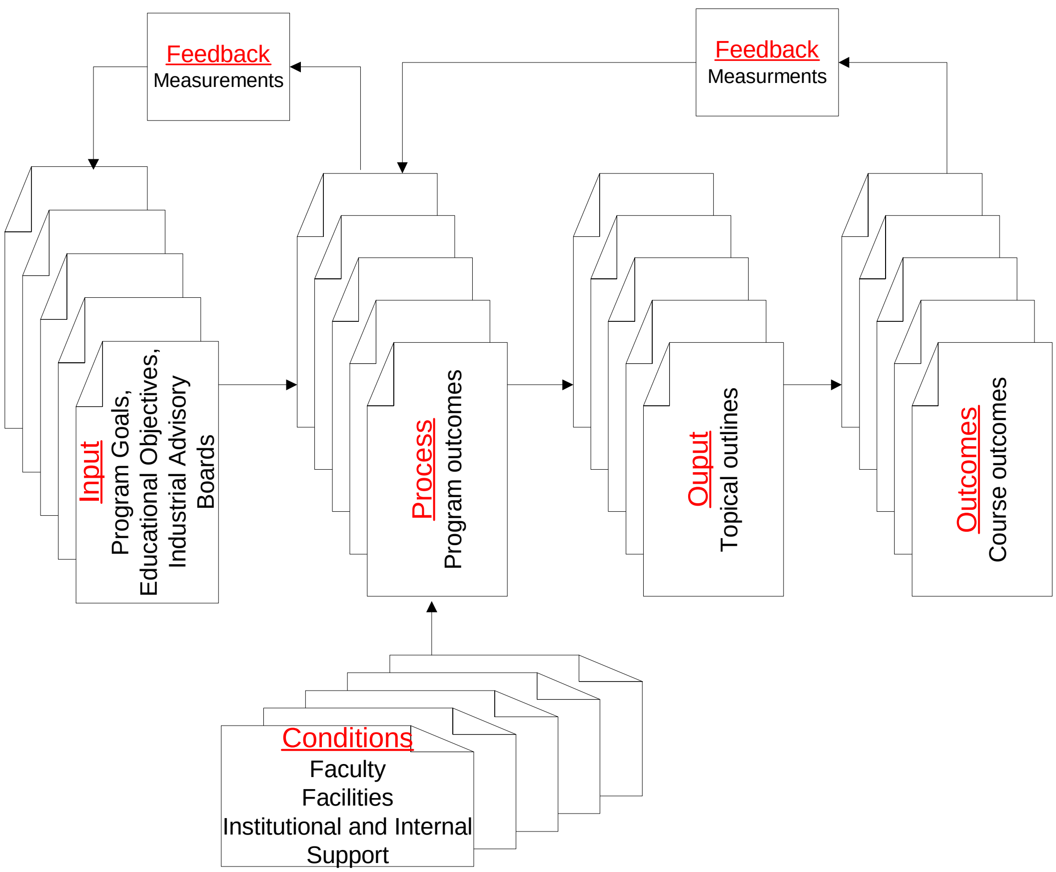

Figure 1. Continuous Improvement Program Diagram

There are two feedback loops: the process (program outcomes) could be modified as a result of measurable feedback from course outcomes. The input (program goals and objectives) could also be modified as a result of modifications in program outcomes. It is also clear that the amount of internal and external support, available equipment, state of facilities, and qualifications of faculty members provide unique input to the process and are responsible for diverse output and outcomes. As an example, an ability of University of Pittsburgh in Johnstown to acquire power systems simulator led to a variety of laboratory and lecture topics to be introduced. Similarly, acquisition of power electronics set of modules by LabVolt allowed Buffalo State College to offer a senior elective laboratory course in this discipline. Likewise, recent donation of digital relays set by Schweitzer Engineering Laboratories to Buffalo State changed topical outlines and added laboratory experiments to their power systems and other EET courses.

In Fig. 1 multiple documents reflect different programs, such as EET, MET, and other programs within Engineering Technology as well as outside the unit itself. Business, Computer Information Systems, Creative Studies, Math and Physics are among them. All these layers should be coordinated as well for optimal course and program outcomes. The same is true for coordination between institutions. In this case CIPs of each participating institution should be synthesized to provide for a better process. Coordination and consultations between different entities is important and provides benefits to the profession despite organizational structure in different institutions.

What Have The Author's Found?

1. The requirements by ABET for preparation to better document student outcomes, course content and laboratory content has allowed this kind of comparison to be done.
2. Different institutions will naturally have somewhat different courses in the same general area. Such differences come from interaction with industrial advisory committees, input from graduates, and the expertise of the instructors. Additional differences will come from the number of courses allocated by the EET curriculum to required power courses and to technical electives available to the students.
3. While the course content may be similar between institutions, the course student outcomes may be written differently. Some institutions may rely on the power courses to demonstrate areas like lifelong learning, impact of technology on society and capstone experiences, others may use alternate courses to fulfill these requirements.
4. Areas like an understanding of lifelong learning and ethics might also be measured by a PEO rather than just a PO, as now used by TAC of ABET.
5. Project Management is not now taught in the power courses, but this is a possible use for it in EET curricula.
6. A survey such as this one can help an institution justify better laboratory equipment and more power electives in its curriculum.

Conclusions

Institutions can learn by comparing their courses with others whose mission is similar. After consultation with industrial advisory boards and alumni, the faculty may choose to alter their current courses. Such consultation and thought can result in very significant changes in courses, or may only result in minor changes.

The three institutions who have participated in this study will make such decisions over the next year or two, but it will take a few years for course changes and equipment purchases to impact their curricula. Some institutions may choose not to make significant changes, but to evolve their curricula into what their constituencies will recommend.

The authors have concluded that yet another influential input besides IABs and alumni should be in the form of consultations between institutions with similar programs. Creating a consortium (regional or even broader) of institutions with power-related programs would serve this purpose well, although other forms of cooperation are possible.

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