Update on the Development of an Electrical Power Technician Associate Degree Program

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Glenn T. Wrate received his B.S.E.E. and M.S.E.E. from Michigan Technological University (MTU) in 1984 and 1986, respectively. While attending MTU, he worked for Bechtel Power Corporation on the Belle River and Midland power generating stations. After graduating MTU, he worked for the Los Angeles Department of Water and Power from 1986 to 1992, primarily in the Special Studies and High Voltage DC (HVDC) Stations Group. He returned to MTU in 1992 to pursue a Ph.D. in Electrical Engineering. While completing his research he worked in the relay testing group at Northern States Power Company in Minneapolis. After obtaining his Ph.D., Glenn accepted an appointment as an Assistant Professor in the Electrical Engineering and Computer Science department at the Milwaukee School of Engineering (MSOE). In 1999 he was promoted to Associate Professor, in 2001 he won the Falk Engineering Educator Award and was promoted to head the Master of Science in Engineering (MSE) program. He received the Karl O. Werwath Engineering Research Award in 2003. In 2004 he moved from the MSE program to take over the Electrical Engineering program. After guiding the program through accreditation, he stepped down in 2007. Dr. Wrate has now returned to his boyhood home and is teaching at Northern Michigan University. He is a member of HKN and IEEE, a Registered Professional Engineer in California, and is a past chair of the Energy Conversion and Conservation Division of ASEE.

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Abstract

This paper presents the current status of an associate electrical engineering technology degree program in the electric power field. While many other programs in the electric power field have tried to focus on renewable energy to increase student interest, this program has focused on maintenance and testing of the existing power grid. This does preclude some of the graduates from working with renewables, and many of the students take elective courses in renewable technologies, but the primary focus of the program is on traditional systems and equipment. This paper looks at the difficulties in student recruitment, the level of rigor required in the courses to provide effective employees, the technical challenges of running labs with industrial-sized equipment, and the need to possibly transition some of the students into baccalaureate degree programs.

Many traditional electrical engineering programs have begun to grow again in the last several years, but most electrical engineering technology programs have either been stagnant or have seen declining enrollments. While this program is relatively new, the trend in enrollment has been positive. These enrollment improvements are similar to several other engineering technology programs, and comparisons to their initiatives and the methods used are made.

The level of rigor in the program's coursework has been closely monitored by the faculty and industry representatives to determine if algebraic-based mathematical derivations are sufficient. In addition, problems with student testing of 2,500 kVA three-phase transformers, 333 kVA single-phase transformers, and student operation and testing of 72.5 kV puffer SF_6 circuit breakers, and industry-standard voltage regulators are covered along with suggested precautions and simplifications. Finally, the difficulties seen in more fully developing the student's potential when there is such a high demand for students with only associate degree credentials is covered.

Background

The Electric Power Technician Program at Northern Michigan University (NMU) in Marquette, Michigan was developed in response to the needs of local industry and as an offshoot of the successful Electrical Line Technician Program[1]. While the Electrical Line Technician Program (Line Tech) is a pre-apprenticeship, two-semester diploma program; the Electric Power Technician Program (Power Tech) is a two-year, associate degree program. Courses taken in the associate degree program are transferable into a four-year Electrical Engineering Technology baccalaureate degree program. The Line Tech program prepares students to install and maintain overhead and underground lines that supply energy to residential, commercial, and industrial customers, and connect generation facilities into the power grid. The Power Tech program focuses on power and auxiliary transformers, circuit breakers and other station apparatus, and protective relays.

Enrollment Trends

As reported by Dr. Brian Yoder of ASEE[2], many traditional electrical engineering programs have begun to grow again in the last several years. The number of BSEE graduates per year reported to ASEE is shown in Figure 1. At the same time most electrical engineering technology programs have either been stagnant or have seen declining enrollments[3]. While the Power Tech program at NMU is new, the overall trend in enrollment has been positive. This is shown in Figure 2. These enrollment improvements are similar to several other engineering technology programs when adding power systems courses to their curriculum[4]. While positive, more work needs to be done to get individual course enrolments to the level preferred by the university (approximately 20 students per course). The oscillation in course enrollment has also been a concern. Based on applications received and enrollment in the first-year courses, the two Power Tech courses scheduled for the Fall 2016 semester will be at or above Fall 2015 levels. Unlike other programs, we have chosen to not emphasize "green power" courses or on-line offerings in the program and enrollment has been positive.

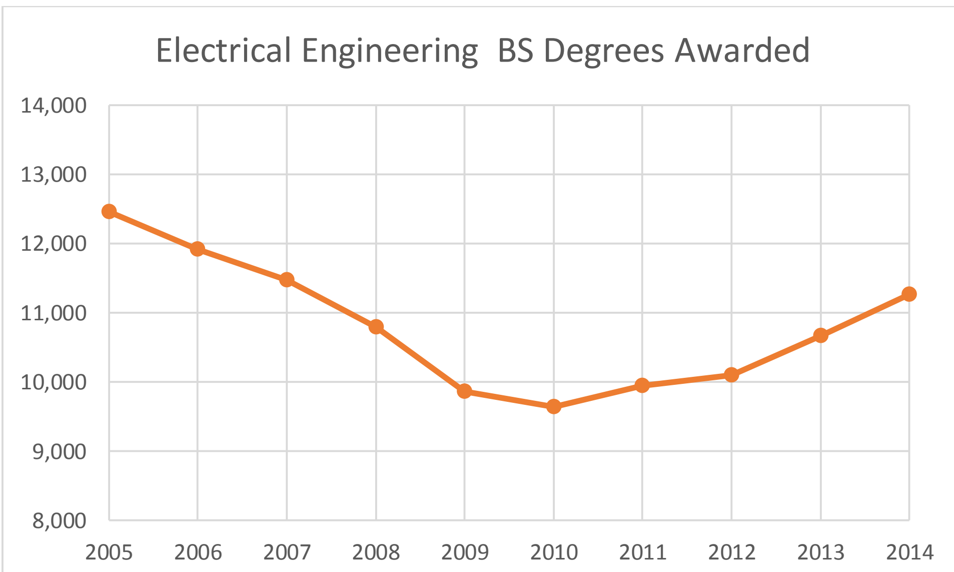

Figure 1. Number of BSEE Graduates per Year

Core Courses

The level of rigor in the program's core courses has been closely monitored by the faculty and industry representatives to determine if algebraic-based mathematical derivations are sufficient. Thus far the students' performance in the courses, their job placement (100%), and the high degree of satisfaction in the program based on alumni interviews indicate that the level of rigor is sufficient. Visits by industry representatives and by members of the Engineering Technology Department's Advisory Board also indicate the rigor is appropriate. The core courses in the program are described in detail below. Because this is an associate degree level program, it does not have the full complement of courses found in other EET power programs[5, 6].

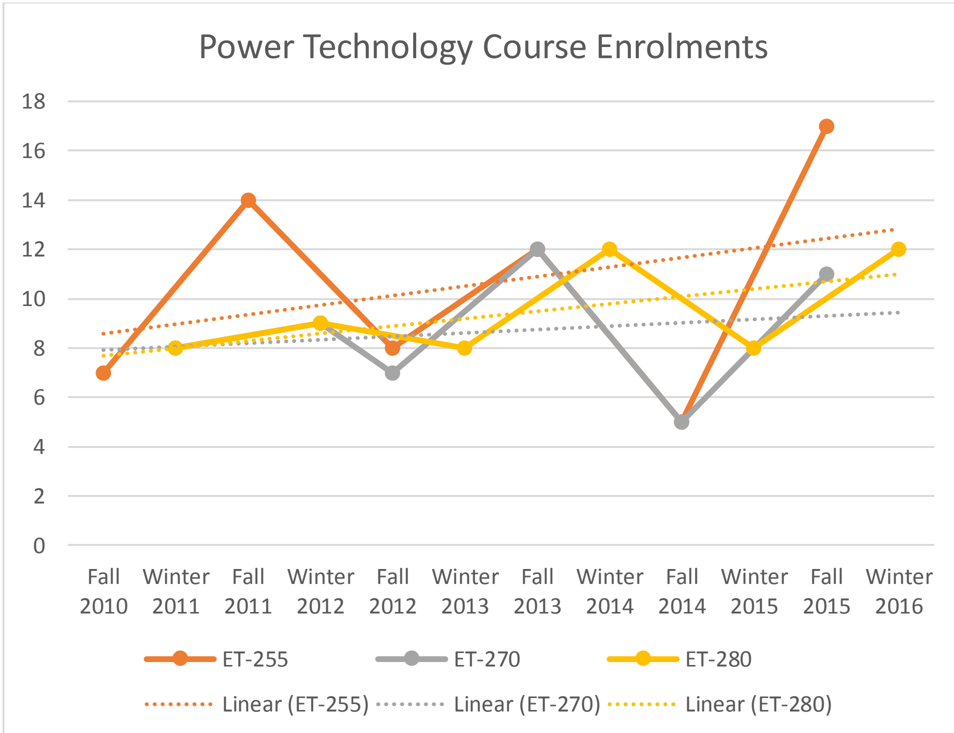

Figure 2. Enrollments in the Three Sophomore-Year Power Tech Courses

ET-255 Transformers

ET-255 is taken the first semester of the student's second year in the two-year Power Technician Associate Degree Program at NMU. In this course the student is introduced to the types of transformers commonly used in power distribution networks. Standard configurations, construction and auxiliary equipment are introduced, along with typical maintenance procedures. A course in AC analysis (ET-113) is required before taking this course. Generally, the students have also taken an introduction to electrical power systems course (ET-180). The objective of the course is to provide the student with a solid foundation in the power and auxiliary transformers used in the electrical power industry today. State of the art testing equipment is used on donated three-phase and single-phase power transformers, voltage regulators, and instrument transformers. This equipment is either in the laboratory or in a mock electrical distribution substation adjacent to the building. The student gains theory, lab experience and actual application testing transformers of the same size as those found in industry. Lecture topics for the course consist of the following:

1. Magnetic Circuit Fundamentals and Magnetic Materials
2. Transformer Fundamentals
3. Open-Circuit and Short-Circuit Tests
4. Complete Transformer Model
5. Transformer Categories: Insulating Medium and Tank/Core Construction

6. Transformer Categories: Application and Use
7. Transformer Polarity, Terminal Markings, and Connections: Single-Phase Transformers
8. Three-Phase Systems and Three-Phase Power Calculations
9. Transformer Polarity, Terminal Markings, and Connections: Three-Phase Transformers
10. Transformer Characteristics
11. Preventive Maintenance of Transformers
12. Transformer Installation, Acceptance, and Maintenance
13. Dry-Type Transformers
14. Liquid-Type Transformer
15. Transformer Testing
16. Online Condition Monitoring
17. Deterioration of Insulating Oil
18. Insulating Oil Testing
19. Combustible Gas Analysis of Insulating Oil
20. Fundamentals of Auto Tap Changers
21. Power Factor and Dissipation Factor Testing
22. General Instructions for the Operation of the Megger PF Test Set
23. Basic Test Connections
24. Instrument Transformers
25. Current Transformers
26. Voltage (Potential) Transformers
27. Polarity Testing of Instrument Transformers
28. Ratio Testing of Instrument Transformers
29. Winding and Lead Resistance Measurements
30. Burden Measurements
31. Fundamentals of transformer protection
32. Harmonics and Power Transformers

Laboratory topics include:

- Insulation Resistance testing on Single-Phase and Three-Phase Transformers, Voltage Regulators, and Instrument Transformers
- Transformer Turns-Ratio testing on Single-Phase and Three-Phase Transformers, Voltage Regulators and Instrument Transformers
- Oil Breakdown testing
- Power Factor testing using the Megger Delta 3000

ET-270 Three-Phase Power Equipment

This course is usually taken at the same time as ET-255. Theoretical and practical aspects of three-phase electrical power generation and distribution are covered, along with the equipment used in the distribution system. Apparent, reactive and true power, power factor correction and harmonics in three phase systems are also covered. Both a course in AC analysis (ET-113) and an introduction to power systems course (ET-180) are required before taking this course.

Lectures and readings in this course focus on theory, design, applications and testing of the typical three-phase equipment found in the industry today. Safe practices and procedures in electrical substations is a priority. Labs consist of testing substation equipment such as power circuit breakers, reclosers, and DC control systems, with some of the most modern equipment found in the industry today. This equipment is either in the laboratory or in a mock electrical distribution substation adjacent to the building. Lecture topics for the course consist of the following:

1. Electrical Safety, Switching Practices, and Precautions
2. Circuit Breaker Travel Time Testing Basics
3. Circuit Breaker Wiring Basics
4. Using the Doble Travel Time Tester software and hardware
5. Circuit Breaker Control Power
6. Reviewing the results of Travel Time Testing
7. Circuit Breaker Insulation Resistance and Contact Resistance Testing
8. Circuit Breaker Hi-Pot and Power/Dissipation Factor Testing
9. Reviewing the results of Insulation and Contact Resistance Testing
10. Grounding Basics: System versus equipment grounding, types of grounding
11. Understanding ground resistance
12. Maximum ground resistance values, ground resistance measurements
13. Reviewing the results of Ground Resistance Testing
14. Touch potential measurements, Clamp-On ground resistance measurements
15. Maintenance of SF_6 equipment
16. Fundamentals of Station Batteries and Chargers
17. Maintenance and Care of Batteries
18. Battery Tests
19. Review Results of Battery Tests
20. Fundamentals of Preventative Maintenance of HV Equipment
21. Planning an EPM Program
22. Overview of Testing and Test Methods
23. Review of Dielectric Theory and Practice
24. Insulating Materials for Electrical Power Equipment
25. Power Quality: Fundamentals and Origins
26. Load Characteristics
27. Effects of Harmonics on Power System Equipment
28. Power Quality Measurements
29. Review Power Quality Test Results
30. Mitigation Techniques

Lab Topics

- Safety
- Mock Substation Setup
- Circuit Breaker Travel Time Testing

- Insulation Resistance and Contact Resistance Testing
- Power Factor / Dissipation Factor Testing
- Ground Testing
- DILO Field Testing
- Battery Impedance and Connection Resistance Tests
- Individual Testing of Recloser
- Power Quality Measurements

ET-280 Protective Relay Systems

ET-280 is taken the second semester of the student's second year in the two-year Power Technician Associate Degree Program at NMU. This course looks at protective relay systems that are used to insure dependable distribution of electrical power. The system is developed from the basics of relay operation to modern communication-based relay tripping. Before taking this course, the student has taken courses in AC and DC analysis, an introduction to electrical power systems (all in their first year); transformers and, generally, three-phase power equipment (in the first semester of their second year). All of the courses in the two-year associate degree transfer into a four-year baccalaureate degree, so some of the students continue. Also, some of the students in the four-year program take this course as an elective.

The student learning objectives of the course are that upon successful completion of the course, the student will be able to:

1. Understand and be able to calculate values using the per unit system
2. Understand and be able to calculate values using symmetrical components
3. Determine the operating characteristics and proper application of auxiliary transformers used with protective relays
4. Contrast the different types of bus protection schemes and determine the operating characteristics and application of each type
5. Understand the application distance relays and zones of protection

As with many courses on this topic, Protective Relaying: Principles and Applications, 4th Edition by J. Lewis Blackburn and Thomas J. Domin is the required textbook[7] for the course. The lecture topics for the course include:

1. System Protection Overview
2. Per unit and percent values
3. Phasors and Polarity
4. Introduction to Symmetrical Components
5. Sequence elements and networks
6. Sequence fault calculations
7. Relay inputs
8. Basic Design Principles
9. Generator or Intertie Protection
10. Transformers

11. Reactors
12. Capacitor Banks
13. Bus Protection
14. Line Protection
15. Pilot Protection
16. Stability

Resources

In the ET-255 course listed above the students test a 2500 kVA three-phase transformer in the mock substation (shown in Figure 3 and Figure 4); and a 333 kVA single-phase transformer, a voltage regulator, and several instrument transformers in the laboratory. In the mock substation the students also investigate the operation of and perform testing on a 72.5 kV puffer SF_6 circuit breaker (the circuit breaker is shown in Figure 5 and the battery bank for the circuit breaker controls is shown in Figure 6) in the ET-270 course. In this course the students also test a recloser and test and maintain a 125 V battery system in the laboratory. The laboratory also contains several racks of Schweitzer Engineering Labs SEL-221 and SEL-321 microprocessor-based protective relays, along with Westinghouse and other manufactures electromechanical relays. Some the equipment in the mock substation is shown in the following figures. In addition to the station apparatus, test equipment is required. A partial list of the test equipment used is given below.

Table 1. Partial List of Test Equipment

Device	Manufacturer	Model
Transformer Turn-Ratio Test Set	Megger	TTR 320
Oil Test Set	Megger	OTS 60 PB
Power Factor Test Set	Megger	Delta 3000
Thermal Imager	Fluke	TIR1
Micro Ohmmeter	DV Power	RM0200G
Circuit Breaker Tester	Doble	TDR 900
Current Amplifier	Doble	F6300
Power System Simulator W/Control & Auto Module	Doble	F6150 & F6910
Moisture Measuring Device	Dilo	3-037-R002
Gas Reclaiming Cart	Dilo	D-340-R001 SFG

When working with this equipment, student safety should be paramount. High voltages, above 10 kV, are available from some of the equipment, i.e., the Megger Delta 3000 power factor test set. Also, the students must make connections on top of large pieces of equipment. The first time teaching the course, ladders were used. One improvement, seen in Figure 4, is the use of scaffolding. One of the simplifications that we have adopted was to only perform one of the possible tests, rather the entire bank of tests available on the test equipment. Also, classes need to be broken down into small groups to allow everyone to use the equipment.

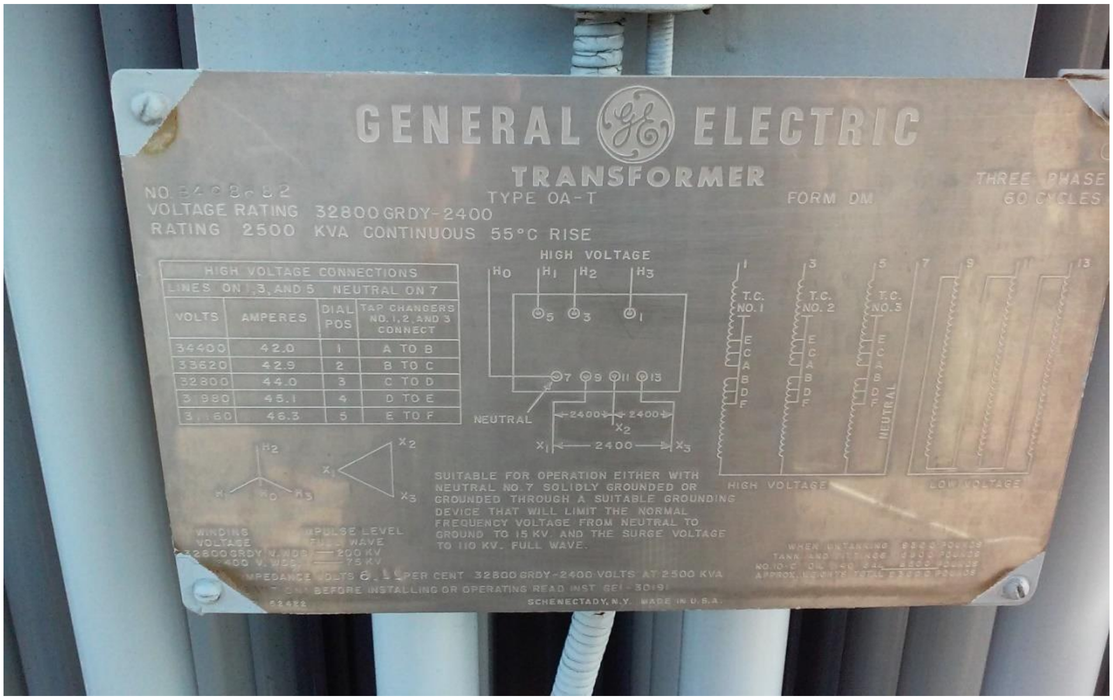

Figure 3. Nameplate of Three-Phase, 2500 kVA Transformer

Figure 4. Students Performing an Insulation Resistance Test on a Three-Phase, 2500 kVA Transformer

Figure 5. Students Testing the 72.5 kV Puffer SF6 Circuit Breaker

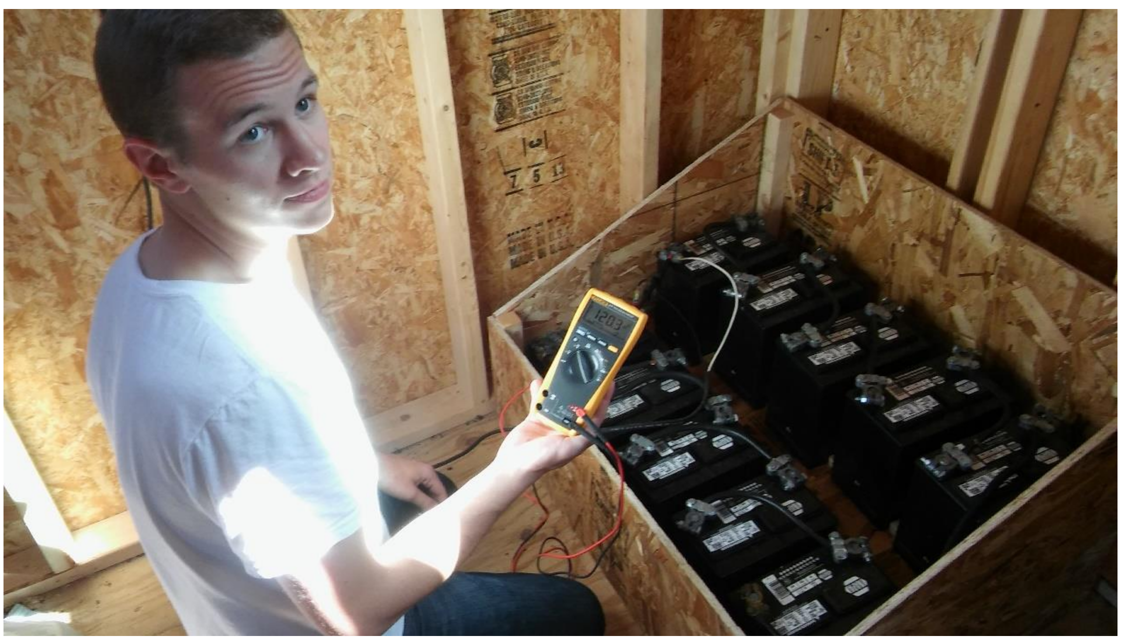

Figure 6. Testing the Control Power for the Circuit Breaker

Two-Year versus Four-Year Degrees

All faculty strive to fully develop their student's potential. When the student stops at the associate degree it is very similar to preparing them for a trade. While it is possible, upward mobility within their profession is limited. It is quite possible they will remain at the tester level for the duration of their career. With a baccalaureate degree it is much more likely that the student will promote into higher levels, either in operation, design, or management. That said, it is difficult to convince the students to stay another two years when there is such a high demand at the associate level. Last year, all of our associate level students seeking employment were placed with an average starting salary of $57,500 per year. It should be noted that one of our four-year students was placed with at a starting salary of $80,000. With guest lectures from alumni, and through our own lectures, we try to focus on the benefits of the four-year degree.

Table 2. Graduates from Two-Year Program

Term	Graduates	Continuing on to Four-Year Degree	Average Starting Salary
Fall 2012	3	0	Not Requested
Winter 2013	7	4	Not Requested
Fall 2013	2	0	$62k (Only one reply)
Winter 2014	10	4	No Replies
Fall 2014	4	2	$58k (Only one reply)
Winter 2014	8	3	$57.5k

Conclusions

The Electric Power Technician Program at NMU is one example of an electrical engineering technology associate degree level program that is growing. The courses are taught at a level, and with the appropriate content, that the students can manage; while still being able to be meet the needs of industry. The resource requirements are substantial, so the backing of local industry is critical. The size and potential hazards of the equipment used in the laboratory must be considered and this equipment must be properly maintained.

Acknowledgment

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