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ELECTRIC UTILITY TRANSMISSION AND DISTRIBUTION LINE ENGINEERING PROGRAM

Final Report for Period October 2007 to August 2010

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PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY
Electricity Delivery and Energy Reliability

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DISCLAIMER

List of Acronyms and Definitions

Blackstart	-	Refers to the process of energizing a power system after a complete system collapse (blackout) has taken place.
BPA	-	Bonneville Power Administration - Owns and operates one of the nation's largest high voltage transmission systems.
EPRI	-	Electric Power Research Institute - An independent, non-profit company performing research, development and demonstration in the electricity sector for the benefit of the public.
EPRI-OTS	-	Electric Power Research Institute - Operator Training Simulator – A generic power system simulator design to provide system operators with experience in operating a power system under various fault conditions.
LiDAR	-	Light Detection and Ranging - Airborne mapping technique used by power companies to provide accurate geospatial data of transmission lines.
NERC	-	North American Electric Reliability Corporation - Organization of electrical grid operators that is responsible for ensuring the reliability of the North American bulk power system.
NESC	-	National Electrical Safety Code - Set of rules aimed at safeguarding individuals involved in the installation, operation, or maintenance of electric supply lines and equipment.
PUD	-	Public Utility District
REA	-	Rural Electrification Act (of 1936) - A set of publications and manuals developed to support rural electric power companies.
Recovery Plan	-	Set of instructions to assist power system operators restart their system after a complete system collapse or major power interruption.
T&D	-	Transmission and Distribution
VAR	-	Volt-Ampere Reactive
WECC	-	Western Electricity Coordinating Council - Regional organization responsible for coordinating and promoting bulk system reliability in the Western Interconnection.

Executive Summary

Economic development in the United States depends on a reliable and affordable power supply. The nation will need well educated engineers to design a modern, safe, secure, and reliable power grid for our future needs. An anticipated shortage of qualified engineers has caused considerable concern in many professional circles, and various steps are being taken nationwide to alleviate the potential shortage and ensure the North American power system's reliability, and our world-wide economic competitiveness.

To help provide a well-educated and trained workforce which can sustain and modernize the nation's power grid, Gonzaga University's School of Engineering and Applied Science has established a five-course (15-credit hour) Certificate Program in Transmission and Distribution (T&D) Engineering. The program has been specifically designed to provide working utility engineering professionals with on-line access to advanced engineering courses which cover modern design practice with an industry-focused theoretical foundation. A total of twelve courses have been developed to-date and students may select any five in their area of interest for the T&D Certificate. As each course is developed and taught by a team of experienced engineers (from public and private utilities, consultants, and industry suppliers), students are provided a unique opportunity to interact directly with different industry experts over the eight weeks of each course.

Course material incorporates advanced aspects of civil, electrical, and mechanical engineering disciplines that apply to power system design and are appropriate for graduate engineers. As such, target students for the certificate program include:

- recent graduates with a Bachelor of Science Degree in an engineering field (civil, mechanical, electrical, etc.),
- senior engineers moving from other fields to the utility industry (i.e. paper industry to utility engineering or project management positions), and
- regular working professionals wishing to update their skills or increase their knowledge of utility engineering design practices and procedures.

By providing graduate educational opportunities for the above groups, the T&D Program will help serve a strong industry need for training the next generation of engineers in the cost-effective design, construction, operation, and maintenance of modern electrical transmission and distribution systems.

In addition to developing the on-line engineering courses described above, the T&D Program also focused significant efforts towards enhancing the training opportunities available to power system operators in the northwest. These efforts have included working with outside vendors to provide NERC-approved training courses in Gonzaga University's (GU) system operator training facility, support for an accurate system model which can be used in regional blackstart exercises, and the identification of a retired system operator who could provide actual regional training courses.

The GU system operator training facility is also being used to recruit young workers, veterans, and various under-represented groups to the utility industry. Over the past three years students from Columbia Gorge Community College, Spokane Falls Community College, Walla Walla Community College, Central Washington University, Eastern Washington University, Gonzaga University, and various local high schools have attended short (one-day) system operator training courses free of charge. These collaboration efforts has been extremely well received by both students and industry, and meet T&D Program objectives of strengthening the power industry workforce while bridging the knowledge base

across power worker categories, and recruiting new workers to replace a predominantly retirement age workforce.

In the past three years the T&D Program has provided over 170 utility engineers with access to advanced engineering courses, been involved in training more than 300 power system operators, and provided well over 500 college and high school students with an experience in running a power system simulator and an exposure to various utility-related professions and craft trades.

Public Benefit from Project

As the utility industry starts replacing much of the 40 to 70 year old transmission and distribution infra-structure in use today, it will require a significant number of skilled engineers with detailed technical knowledge of industry practice and design procedures. Unfortunately, recent studies indicate 20% to 40% of highly skilled engineers currently engaged in utility system design practice are due to retire within the next decade. These same studies also indicate there are insufficient junior engineers with the necessary design skills and knowledge available to replace them, and that it will be necessary to increase recruiting and training efforts of new graduates and senior engineers from other industries to meet the required demand. The T&D related courses developed as part of this project have been designed to meet this need. Engineers taking these courses will significantly increase the depth and breadth of their technical skills and knowledge of utility system design practice. The project, therefore, has an immediate and direct benefit to the public by providing a pool of talented utility engineers to replace those planning to retire, and by increasing the number of engineers that have been well trained by knowledgeable senior utility engineers.

Accomplishments

All tasks assigned over the project period have been completed. The assigned tasks involved developing seven, utility-focused, graduate level engineering courses (listed below), overall management of project related activities, and the development of a northwest regional power system model for use in System Operator training activities (see Appendix A).

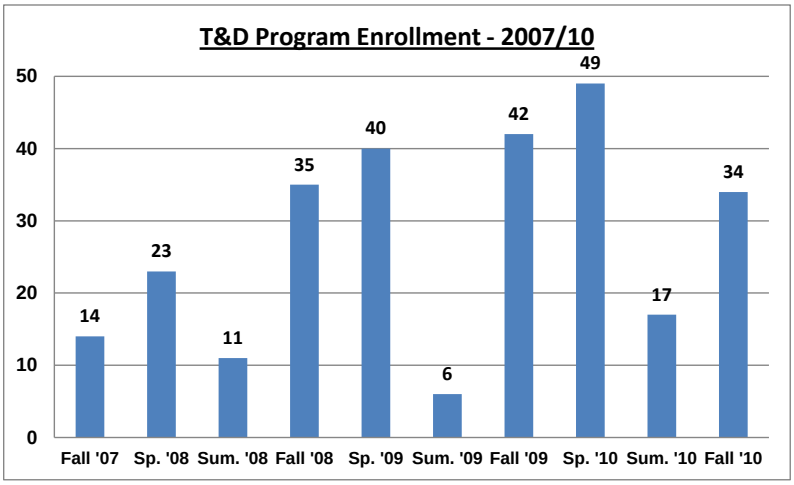
- Task 1.0 - Substation Design
- Task 2.0 - Protective Relaying
- Task 3.0 - Power System Analysis and Design
- Task 4.0 - Electrical Aspects of T-Line Design
- Task 5.0 - Grid Automation
- Task 6.0 - Underground Transmission Systems
- Task 7.0 - Engineering Leadership
- Task 8.0 - Project Management and Reporting
- Task 9.0 - Northwest Regional System Model Development

On-Line Course Enrollment and Rotation (2007 – 2012)

Total course enrollment (by semester) since initiation of the on-line program is shown in the chart below, with actual courses offered (by session) shown in the following page.

Based upon student feedback, the drop in fall 2010 registered students is believed to be due to a recent change in tuition reimbursement practices by many utilities. Instead of providing reimbursement for any engineering related course, many utilities now offer reimbursement for degree-granting programs only. Such a change was anticipated by many of our T&D adjunct faculty some time ago and, as such, T&D program staff has requested a change from a certificate only graduate program to a full Master of

Engineering Degree Program in T&D Engineering. Based on the level of potential student inquiries for such a program, we anticipate an increase in enrollment if the new degree program is approved. The degree program request has been submitted to the university academic council for approval, after which it will progress to the faculty senate, President of the University, Board of Regents, and then the Board of Trustees. Should approval be obtained at each level the new program will be in place by fall 2011. T&D program staff has also increased efforts to make industry more aware of our on-line courses by attending professional meetings, industry-sponsored conference events, advertising in industry-related publications, and advertising on-line with a focus on younger engineers. Overall, students taking our courses provide positive feedback on both the program's technical content and method of delivery.



	2007/2008 School Year			
	Fall07		Spring 08	
	Session I	Session II	Session I	Session II
	T-Line Design - Introduction	Electrical Grid Operations	Electrical Dist. System Design	T-Line Design - Introduction
	Project Dev. & Construction Methods			Electrical Grid Operations
2008/2009 School Year				
Summer 08	Fall 08		Spring 09	
	Session I	Session II	Session I	Session II
T-Line Design - Advanced	Electrical Grid Operations	Electrical Dist. System Design	T-Line Design - Introduction	T-Line Design - Advanced
Project Dev. & Construction Methods	System Protection	Substation Design		Project Dev. & Construction Methods

2009/2010 School Year				
Summer 09	Fall 09		Spring 10	
	Session I	Session II	Session I	Session II
	Electrical Dist. System Design	Grid Automation	T-Line Design - Introduction	T-Line Design - Advanced
Power System Analysis	System Protection	Substation Design	Power System Analysis	System Protection
	Electrical Grid Operations	T-Line Design - Electrical Aspects		Project Dev. & Construction Methods
2010/2011 School Year				
Summer 10	Fall 10		Spring 11	
	Session I	Session II	Session I	Session II
Grid Automation	Electrical Dist. System Design		T-Line Design - Introduction	T-Line Design - Advanced
Engineering Leadership		Substation Design	Power System Analysis	System Protection
	Electrical Grid Operations	T-Line Design - Electrical Aspects	T-Line Design - Underground	Project Dev. & Construction Methods
2011/2012 School Year				
Summer 11	Fall 11		Spring 12	
	Session I	Session II	Session I	Session II
As required	Electrical Dist. System Design	T-Line Design - Electrical Aspects	T-Line Design - Introduction	T-Line Design - Advanced
As required	Project Dev. & Construction Methods	Substation Design	Power System Analysis	System Protection
As required	Electrical Grid Operations	Grid Automation	T-Line Design - Underground	Engineering Leadership

System Operator Training

In addition to the assigned tasks listed above, we have also offered NERC-approved training courses for Power System Operators and related occupations, provided Veterans with the initial training required for entry into System Operator type positions, used our System Operator training room to provide university and college students with an exposure to power system operations, and regular school children with an experience operating a simulated power system. The program staff believe the operator training courses will help improve overall power system reliability in the Pacific Northwest, and that our outreach activities to students will encourage more young workers to enter the power industry and be better prepared to work on the power grid of the future.

Following a recent informal survey of northwest power utility managers to determine regional training needs, the following NERC related courses will be offered in our training facility over the next 13 months to System Operator throughout the northwest.

Course Title	Date
Systematic Approach to Training	Dec. 1-3, 2010
Principles for System Reliability	Dec. 7-10, 2010
NERC Certification Preparation	Dec. 14-16, 2010
NERC Certification Preparation	Feb. 15-17, 2011
Critical Decision Making	Mar. 15-18, 2011
NERC Certification Preparation	Apr. 12-14, 2011
Principles for System Reliability	May 17-20, 2011
NERC Certification Preparation	May 24-26, 2011
NERC Certification Preparation	July 12-14, 2011
Critical Decision Making	Aug. 23-26, 2011
NERC Certification Preparation	Sept. 20-22, 2011
Critical Decision Making	Oct. 18-21, 2011
NERC Certification Preparation	Nov. 15-17, 2011
Principles for System Reliability	Dec. 13-16, 2011

Wide Area System Training

A further outcome of the above survey was a realization that a strong need existed for a wide-area approach to operator training using accurate regional system models, rather than the generic EPRI-Operator Training Simulator (OTS) model. While the generic model is suitable for introductory level operator training, individual company system models with the appropriate tie-lines between each model (a regional system model) is necessary to simulate the actual failure and blackstart scenarios which are likely to be encountered in practice. Using the regional power system model developed in this project (see Task 9 above), six, two-day training sessions were conducted in November 2010 for system operators from five major northwest utilities (BPA, Avista, Grant County PUD, Douglas County PUD, and Chelan County PUD). These training sessions have proven to be extremely successful in terms of identifying problem areas in the existing utility blackstart recovery plans. Follow-up action items from these training sessions will involve a review of each participating utility's recovery plan and, perhaps much more important, the involvement of operators from surrounding utilities in reviewing proposed plan updates and changes. An outline of topics covered in these recent training sessions is provided in Appendix B.

Over the longer term we intend to expand these training opportunities to include multiple training locations throughout the northwest with remote sites (either individual utilities or their local community college) participating in the exercise by means of GU's Blade computer. This unique, realistic simulator training is expected to improve reliability and allow system operators to restore power more effectively in emergency conditions.

Other Activities

T&D Program staff has worked with Spokane WorkSource unemployment office to offer T&D courses to recently-laid off electronics engineers. These engineers are now in transition to the power industry and their enrollment numbers continue to grow from one in fall 2007 to eight in fall 2010. Many of the original engineers have now completed the five-course certificate program and are actively employed by power-related companies in the northwest.

Problems Encountered

Difficulties in recruiting qualified industry experts that were willing to help develop the required course resulted in significant delays in completing four courses (Substation Design, Electrical Aspects of T-Line Design, Underground Transmission Systems, and Engineering Leadership). Although almost all senior engineers approached appreciated the value of the proposed program and expressed a strong desire to offer their services as instructors, very few would follow through when the duties, responsibilities, and time commitments were outlined. In more than a few cases individuals made a solid commitment to develop course material but could not deliver on schedule. In these cases it became necessary to find a replacement instructor and start the process again on a condensed timeline to meet the promised course schedule date. For the above four courses it became necessary to extend the initial offering date of the course until all assignments had been completed.

Recruitment of adjunct faculty/industry experts is the most important part of the overall process. As a group they tend to have very limited time to spend developing on-line course material. In addition, the overall development process takes significantly longer to complete than many of them originally anticipate. Close communication between T&D Staff and the adjunct faculty is required to bring course development activities and subsequent teaching duties to a successful conclusion.

Project Outcome

The Certificate Program developed in this project aims to provide a target group of engineers with a broad background in utility system operations and design procedures, along with an appreciation of the inner workings of a large interconnected utility. The courses offered allow students to quickly assimilate knowledge typically gained only after many years of utility service, develop an understanding of modern utility engineering and construction practice, and enhance their skill set and ability to accept the challenges of a rapidly changing industry. This allows them to become key players in sustaining industry advances and developing innovative solutions to whatever problems the future may bring.

Contact Information and Links

Additional information on the T&D Program, scheduled courses, and system operator training can be found by following the link below:

www.eng.gonzaga.edu/tandd

or by contacting,

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Appendix A - Course Descriptions

TADP 540 Transmission Line Design – Introduction: Structures, foundation design, conductors, survey techniques, terrain modeling, computer-aided design, NESC code requirements. Students will design sag and tension template by hand and spot a new transmission line.

TADP 541 Electrical Distribution System Design: Distribution System concepts, line and substation design, network planning, conductor sizing, transformer specification & connections, arrestors, underground cabling, substation overview, protection/fusing. Short circuit, load flow, reactive compensation and harmonic analysis. Integration of renewable and distributed generation into the grid.

TADP 542 Substation Design: System overview, design principles, types of substations, components, utilization, scoping a project, project plan, site, scheduling, major equipment, control houses.

TADP 543 Electrical Grid Operations: NERC/WECC reliability standards, control area operation, outage coordination planning, switch theory and devices, reactive load balancing, generation load balancing, per-unit system, network modeling, power flow analysis, system disturbance analysis, and seasonal ratings.

TADP 544 Project Development and Construction Methods: Project development, project proposals to management, project initiation, scheduling, cost management, resource management, permitting authority, land rights acquisition, overview of contracts, contractor selection, and project status tracking.

TADP 545 System Protection: General concepts, voltage and current transformers for protection, classification and functionality of relays, overcurrent protection, distribution feeder protection, high voltage line protection with distance relaying, transformer protection, generator protection, testing and commissioning.

TADP 547 Underground Design: Introduction to cable systems, types of cable systems, basic cable design, cable accessories, installation practices, manufacturing and testing, and application considerations.

TADP 548 Electrical Aspects of Transmission Line Design: Introduction to Electrical Aspects, rules and requirements, design criteria & voltage levels, conductor selection & ratings, clearances, REA manual, insulation, voltage flashover, Electromagnetic Fields, corona, induction coordination, grounding requirements, pole grounding, guy wire grounding, grounding measurements.

TADP 553 System Automation: Economic benefits, reliability, safety, equipment costs, communication, transmission automation, distribution automation, under frequency load shedding, radial overhead, radial loop underground, demand side management, remote connect/disconnect, SmartGrid, consumer automation, network design aspects.

TADP 556: Engineering Leadership: Introduction and definition of leadership, leadership versus management, communication, negotiations, communicating with non-engineers, system thinking, team learning, shared vision, ethics, engineering ethics standards, people management mechanics, building support, and strategic planning.

TADP 640 Transmission Line Design – Advanced: Guyed structures, lattice towers, steel poles, soil properties & foundations under compression, foundations under lateral load, foundations under uplift, advanced sag and tension, special problems in sag and tension, LiDAR technology.

TADP 641 Power System Analysis: Power system modeling, short circuit calculations, load flow algorithms and methods, and harmonic analysis and filter design. Case studies on voltage regulation, VAR control, and relay setting and coordination. Basic concepts of power systems, their components and how they are inter-related. Overview to the topology and players of the North American power grid.

Appendix B

Northwest System Operator Training - Course Outline

Introduction and course overview. (The goal of this unique course is to improve power reliability and provide the best possible training experience for system operators.)

Instructor led step-by-step discussion of each company's power restoration procedure and exercises which are designed to familiarize operators with simulator use. The exercises, which are documented on individual work sheets completed by students, include an initial walk through of procedure steps (including initial cranking path) and the simulator model.

The causes, contributors, and consequences of system wide black out events are presentated, along with the causes and effects of restarting a power system after an extended outage (cold load pick up). The phases of a power system restoration, assessment, preparation of subsystems, and establishment of target systems – including restoration priorities – are discussed.

A review of voltage control including voltage rise on open lines (ferranti rise), importance of maintaining reactive balance and reserves, and the effect of adding load; frequency control during restoration including use of zero droop units, generator limitations, effect of adding load, reserves, and recognition of islanding conditions. Equipment issues that could complicate or otherwise delay a successful power system restoration are discussed in detail.

All applicable NERC Standards and regional guidance for the western interconnection are covered, along with restoration requirements, synchronizing islands, and required notifications.

Using the Power System Simulator and individual company power restoration procedures and drawings, the operators will restore their individual company systems. When stable system islands have been created the operators will follow both NERC and their company procedural requirements to synchronize their systems to outside sources. Documentation will include the Scenario Guide and Operator Log Sheets completed by each company representative.

A written exam will cover knowledge elements discussed in the course.