A NEW M.S. DEGREE THAT COMBINES ELECTRICAL POWER ENGINEERING AND FINANCE

Arthur M. Breipohl, Connie L. Dillon, Fred N. Lee
University of Oklahoma

Abstract

The purpose of this paper is to describe both the content and the delivery method of a new M.S. degree program that combines electrical power engineering and finance. This program is designed to produce M.S. electrical engineers who are prepared for the emerging competitive electrical energy industry. With support from the N.S.F. CRCD program we are implementing this degree program, and we also are developing the material for the two new key courses and a simulator that will be made available to other universities on the web. The paper consists of: a brief description of the changes that are taking place in the electrical energy industry; their effect on the demand for graduates; the curriculum that we are developing; and a description of the two courses and the simulator that we are developing. We also briefly describe our experiments with delivery methods in anticipation of placing material on the web.

I. The Changing Electrical Energy Industry

The introduction of competition is the most significant change that is affecting the sale and production of electric energy. On the sales side, energy companies will eventually compete in a nation-wide market for electricity. Competition already exists at the wholesale level where energy companies buy and sell power from one another at market prices to eliminate expected and unexpected imbalances in load and capacity. Eventually, competition will extend to the retail market in which electricity is sold to businesses and residences.

Competition will affect the production of electricity as well. First, energy companies will become more sensitive to the performance and uncertainty of their equipment, fuel, and capital costs because their reduced, volatile revenues may not cover these costs, and they can no longer simply pass them along to their customers. Second, energy companies will begin recognizing the opportunity costs of providing one service, say generation, in lieu of providing another service, say ancillary services, because they are able to choose the type of service they'll provide to maximize profit in a competitive market.

The importance of these considerations will intensify the need for power system plans and resource schedules that incorporate the best engineering and financial principles and practices. Both scheduling and planning require the integration of engineering knowledge about the physical characteristics of the generators and financial knowledge about the financial tools that can be used to aid in power production and delivery. For example, if a company acquires a lease of a generator for a period of time, it will probably reduce the risk if the company also shorts a forward contract for power delivery.

II. Relationship between the Changes in the Industry and our Curriculum

To compete in this emerging industry, the electrical companies are presently hiring people who are experienced at trading other commodities such as natural gas to supplement the engineers who can operate the power plants. Planning has changed from adding generators to "serve the load" to building, buying or leasing generators to "make a profit". In addition to coming from two different cultures where risk is appreciated or abhorred, the traders and the engineers come from two different backgrounds of knowledge base. Thus we concluded that a program of study that combines electrical power engineering and finance would be very useful education. Most of the firms that we contacted agreed with us. Thus they agreed to support our proposal to the N.S.F. to develop such a curriculum.

III. Outline of Proposed Curriculum

The program leading to a Master of Science degree in Electrical Engineering with specialization in electric power systems comprises 36 hours of course work.

Required Courses (18 hours -- 3 credit hours per course)

Analysis of Electrical Transmission (significant revision of existing course)
Generation Resource Scheduling and Portfolio Optimization for Energy Systems (new course)
Generation Resource Planning for Energy Systems (new course)
Financial Administration of the Firm (existing course)
Derivative Securities and Markets (existing course)
Financial Engineering (new course)

Elective Courses in Engineering, Mathematics, or Physics (18 hours). Possibilities include:

Random Signals; Real Analysis; Control Theory; Linear Algebra; Communications Theory; Digital Systems; Probability and Statistics.

<u>Internships will be required of all students.</u> The students will be required to write a report on their internship experience.

The Two New Courses that Combine Engineering and Finance:
Generation Resource Scheduling and Portfolio Optimization for Energy Systems
(3 credit hours)
This course prepares engineering students to (a) optimally schedule energy system resources (e.g. fuel, generation, transmission, pipeline) to meet committed obligations and participate in energy market trading; (b) optimally manage a trading portfolio which contains positions in generation assets, forward/option contracts of various energy products (e.g. electric energy, electric reserve, fuel); and (c) systematically assess and manage operational and market risks. The contents of this course are designed to focus on operational profit-maximization strategies for energy companies in a risky market environment over a time horizon up to a month. Topics include: market-based scheduling of generation (energy and reserve), fuel, transmission contracts, emissions; energy/reserve bidding strategy; optimization, risk assessment, and risk management of trading portfolios. This course will include extensive "real-world" case studies for each of the covered topics. The teaching materials include technical papers, cases, and a

state-of-the-art teaching simulator. The prerequisite for this course is *Analysis of Electrical Transmission*.

Course Outline:

(a) Overview of resource scheduling & portfolio optimization; (b) Objectives, constraints, and decisions; (c) Operational and market risks; (d) Market-based resource scheduling; (e) Generation (energy and reserve) commitment and dispatch; (f) Fuels and emissions coordination; (g) Multi-market transmission and pipeline utilization; (h) Bidding energy and reserve to a pool; (i) Trading portfolio optimization; (j) Modeling of a forward/option contract as a pseudo generator; (k) Modeling of contract positions (e.g. short a call, long a put etc.); (l) Portfolio optimization and contract valuation (e.g. value of a month long call option); (m) Mark-to-market risk assessment; and (n) Trading portfolio risk management.

Generation Resource Planning for Energy Systems (3 credit hours)

This course introduces students to power system generation planning in a competitive environment. It replaces the traditional course in generation planning that was based on having adequate generation to supply reliability requirements. In this course the emphasis is on price forecasting; scheduling a proposed generator into the forecast price; and then finding both the intrinsic and the extrinsic value of the generator. The intrinsic value is the net present value based on traditional engineering-economic concepts, and the extrinsic value is the additional net present value that arises due to uncertainty, e.g. in prices, and the ability to change decisions (i.e. optionality) on the basis of observation of the uncertain values, e.g. prices, that occur. In addition to the expected profit (both intrinsic and extrinsic values) the risk associated with a generator must be evaluated.

Course Outline:

(a) Decision analysis; (b) price forecasting via geometric Brownian motion and the ln-normal distribution; (c) price forecasting using the RDI supply-demand model; (d) forward price builder; (e) discounted cash flow evaluation; (f) future contracts; (g) option contracts; (h) asset valuation via simulation; (i) inputs to GenTrader; (j) intrinsic value simulation; (k) interpretation of outputs; (l) describing uncertainty in prices, quantities and outages; (m) correlation; (n) simulation outputs/histograms; (o) interpretation of risks; (p) real option evaluation.

IV. The Simulator

Presently we are using a reduced version of a commercial simulator which consists of two stages. The first stage of the model simulates the operation of the asset under specified market conditions; i.e. it simulates optimum hourly exercise decisions. This part of the model, called GENTRADER, is widely used by traders and asset managers to guide operational strategies for an asset or a portfolio of assets and possible financial transactions. This model is designed to use hourly price curves (for ancillary services as well as for energy) and prescribes the portfolio that maximizes profit under the extant physical constraints and financial contracts. The physical constraints can include: heat rates that vary with operational level, lower and upper dispatch limits, minimum up-time and down-time, maximum ramp-rates, constraints on ancillary services, start-up and shut-down costs, fuel and emission constraints, and transmission limitations. Financial contracts can include long or short positions in forward contracts and options, and these contracts can be committed, i.e., they are constraints, or proposed, i.e., they are possible members of the optimum portfolio. The result of this stage of the model is, over a period of time ranging from one hour to ten years, a description of optimal exercise decisions and the resulting profit given a set of market conditions.

The second stage of the model, called EFR, is designed to capture the optionality of the assets when there is uncertainty in market prices, quantity of electricity products taken under a firm contract and availabilities of the assets. First a series of GENTRADER simulations are run to determine operational profit for varying market, quantity, and availability conditions. The conditions for these deterministic scenarios are chosen to span the sample space, i.e. the possible outcomes as determined by volatilities of prices, time between the present and the time of operation, variance of the contract quantities and availability rates. From the results of these simulations the partial derivatives of profit with respect to each of the risk drivers is estimated at a number of locations within the sample space. These partial derivatives, or deltas, then are used to form a describing function, or a piecewise linear function that represents profit over the simulation horizon as a function of the uncertain, or stochastic, variables. Finally Monte Carlo simulation is used to estimate the distribution of profit. The random samples of each stochastic variable are taken on an hourly basis, and these samples can be independent or correlated. Samples from different stochastic processes also can be correlated. Samples for hourly prices are based on a GBM model, which results in lognormal random variables with different hourly mean values, while quantities are assumed to come from a Gaussian stochastic process. Generating unit availabilities and transmission path availabilities are chosen from Bernoulli distributions. The final result is a histogram that estimates the distribution of profit over the simulation horizon, from which expected profit and comprehensive risk measures are evident.

During the course of this project, we intend to create a simpler simulator that accomplishes the same functions, but with a simpler (and therefore more approximate) model.

V. Delivery Method

The goal is to place the material for the two courses described above into a format that is available to others over the web. Also, we have proposed to place some version of the simulator on the web. Because this is a new approach to education for the emerging market for electrical energy, we assume that the material would be useful for other university courses. There is no text available for this material, and thus we assume that the material which we place on the web could be used by an instructor to replace a textbook.

In the present courses we are using powerpoint slides to form the written material for the students, and we are experimenting with various software for video streaming the lectures including the powerpoint slides as a potential format for course delivery.

VI. Technology in Course Design and Delivery

One goal of the project is to provide access to the courses above to other universities and students. During year 1 we explored using technology to both provide access and improve the potential learning benefit.

(a) Access Issues. Our goal here is two fold. First, we wish to make the course materials available to other universities interested in integrating these materials into their own curricula. Second, we hope to make these courses available to students who are currently employed throughout the region.

During year 1, we tested two delivery options using one of the courses, ECE 5973. First we delivered the course to a worksite in Oklahoma City via live interactive video providing two-way voice and video interaction between the sending and remote sites. The technology used was H.323, a compressed video system that can be transmitted via T-1 connections. Second, we made the videotapes of the courses available on the WWW using video streaming technology.

The first delivery option provided these advantages. Students could ask questions and receive immediate feedback, the on-campus students benefited from interacting with students who are currently working in the field, and finally, the instructor could use both group project and student presentation strategies. The primary disadvantages related to technical and organizational issues. Technical problems included equipment incompatibility, a variety of sound problems, and a lack of system redundancy (that is, when a network connection failed, no alternative route was available other than video taping the lecture and making the video tapes available to the students). Second, organizational issues related primarily to the fact that neither the sending nor receiving site provided a central technical support service so that problems could be identified and resolved quickly.

The WWW delivery option provided these advantages. Students could view the material at a time and place convenient to them and they could view the material as often as needed. Again we encountered both technical and organizational problems. The PowerPoint generated graphics do not "stream" well and were often not legible. (We attempted to resolve this problem by making the PowerPoint generated graphics available separately). Organizational issues related to university support. The university currently provides no coordinated support for videotaping classes, graphic design, and Internet services (including streaming). In addition to the streamed lectures, the website provided students with access to the course schedule, all course materials, and e-mail interaction with the professors.

VII. Learning Benefit

All students who enrolled in ECE 5973 for a grade performed well and learned the material, based upon course grades and instructor perceptions. When asked about what factors contributed to their learning, the students cited the ability to view the lectures using the WWW as an important factor. All of the students viewed the lectures repeatedly after attending class. One student viewed them daily. In addition, the students at the remote cite reported re-viewing the video taped lectures more than once to review material.

In addition, we are exploring the use of the WWW to provide students with opportunities to practice new learning. We hope that by making the simulator accessible via the WWW, we will be able to increase the number of simulation exercises required, thereby increasing the potential transfer of learning to a more widely diverse range of problems.

VIII. Conclusions

After one year's experience, we believe that the electrical energy market is still in the transition toward competition, although experiences in California suggest that difficulties and modifications have occurred and will continue to occur. Given that the electrical energy market becomes a competitive market, educational material to prepare students for employment and leadership in this industry seems to be essential. Therefore we believe that we are on the right tract when developing material that combines electrical system operation and planning with finance.

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ARTHUR M. BREIPOHL
Arthur M. Breipohl is currently the OG&E Professor in the School of Electrical and Computer Engineering at the University of Oklahoma. He has published several books and numerous journal and refereed publications. His current research interest lies in power system planning emphasizing probabilistic and stochastic models. He is a Life Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

CONNIE L. DILLON
Connie L. Dillon is a Professor of Adult and Higher Education at the University of Oklahoma, where she specializes in distance education and telecommunications. She is also Director of the Research Center for Continuing Professional and Higher Education, where she specializes in distance learning research. She currently serves on the editorial board for the American Journal of Distance Education. She has been recognized for outstanding research in distance learning by the University Continuing Education Association and for outstanding teaching by the University of Oklahoma Student Association.

FRED N. LEE
Fred N. Lee is currently a Professor in the School of Electrical and Computer Engineering at the University of Oklahoma. He has numerous refereed and journal publications. He has many years of industrial experience. His current research interest lies in power system production scheduling and simulation. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).