RODERICK J. FROWD

QUALIFICATIONS

Mr. Frowd has over 29-years of experience in advanced power system analysis development for power system operation, control and planning, with particular specialization in developing and testing complex generation scheduling applications and conducting reliability and long-term planning studies. He has been active in many modeling and analysis projects for the deregulated industry, including ancillary services dispatch, bid price modeling, and most recently a Must Offer Unit Commitment application using MIP formulations. Mr. Frowd is a Senior Member of IEEE and has authored and coauthored many publications in the generation scheduling area.

Mr Frowd worked for many years in Generation Planning at the State Electricity Commission of Queensland and was involved in several capacity planning studies to evaluate the costs and reliability of future plant expansion scenarios. Advanced Monte-Carlo methodologies coupled with Dynamic Programming were used to evaluate reliability margins, perform cost analysis and evaluate plant scenarios. Since 2003 has been heavily involved at ECCO in developing, implementing and deploying energy simulation market software coupled with Monte Carlo techniques for reliability and market simulation studies.

EDUCATION

- Master of Engineering in Electrical Engineering, University of Florida, Gainesville, Florida, 1980
- Bachelor of Engineering (Honors IIA) in Electrical Engineering, University of Queensland, Brisbane, Australia 1976.

EMPLOYMENT HISTORY

ECCO International, Inc.

Principal Consultant, 2003 – Present

Mr. Frowd has been the leading architect and developer of several ECCO International proprietary software applications. He is key developer of ProMax™, which is used for short-term energy market simulations in a competitive market environment or configured to perform daily unit commitment for a supply company. ProMax™ uses specific market rules and Multi-Integer Programming (MIP) to perform energy market simulations. Mr. Frowd was also the leading architect and developer of ProMaxLT™ which is a long-term reliability and market analysis software platform that utilizes Linear Programming and Mixed Integer Programming optimization methodologies as well as Monte-Carlo modeling techniques to introduce variability in network and resource availability over a time horizon of 30-days to 30-years into the future. Both platforms have been used extensively around the world for reliability studies and short- and long-term market analysis evaluations. Mr. Frowd has also been the leading developer of the CSS™ package which is an application designed to simulate an ISO's financial rights allocation and auction processes.

Polish Transmission System Operator, PSE 2010 - 2011

Mr. Frowd participated in a comprehensive cost benefits analysis of implementing the new LMP-based energy market in Poland by deploying the ECCO's ProMaxLT™ platform. The scope of this work was to quantify the effects and the impacts to the energy market outcome, system dispatch, and resulting production system costs for the Polish power

system under two scenarios: a status quo case ("Base Case") in which scheduling and settlement are based on the current zonal market design, and a case in which LMP based market model is implemented ("Change Case"). The work also included a quantification of the effects and impacts that the market paradigm would have on the Polish market.

TERNA, A Generator 2009 - 2010

Mr. Frowd participated in a major project to analyze and quantify the value of Pump Storage Hydro (PSH) facilities provides to System Operations in Greece in the presence of high penetration of Renewable Energy Resources (RES) and especially wind generation by deploying the ECCO's ProMaxLT™ platform. In this study we focused on quantifying by deploying simulations the reliability benefits PSH facilities provide to the system. The simulation was based on actual data of the Greek generation and transmission data and the current rules of the wholesale Day-Ahead energy market. As part of the study we also deployed the market prices produced from the energy simulations to calculate the capacity payments to the proposed PSH facilities along with the cost savings due to pump operation where PSH facilities pay low prices at night to pump and sell energy during the day at higher prices.

Southern California Edison 2006 - Present

Mr. Frowd has been leading the effort related to SCE's long-term market simulation and LMP forecasting requirements as they relate to valuation of Congestion Revenue Rights in the CAISO market. During the course of this project ECCO has provided long-term, up to 20-years forward, forecasted LMPs. It has used this data to then apply differential factors between pricing nodes to determine the value of CRRs based upon various conditions.

Pacific Gas and Electric 2008 - present

Using ProMax™, Mr. Frowd has been validating LMP market results against the CAISO day-ahead LMP market. ECCO has also been providing to PG&E simulation results to gauge the impact of various market design proposals currently under consideration at the CAISO in the LMP markets. This work has been invaluable in-terms of clearly showing possible flaws in some of the design proposals and has effectively informed PG&E about what pitfalls may exist. It also brings to light what proposals will have a positive benefit to PG&E and other comparable participants.

Hellenic Transmission System Operator, Greece 2008 - 2009

Mr. Frowd has configured the ProMaxLT™ software to the HTSO market for the purpose of studying the impact of various penetration levels of wind generation in Greece. The purpose of the project is to demonstrate the operating and ancillary service requirements necessary to reliably operate the HTSO grid as the penetration level of renewable resources as a wind generation substantially increases.

Regulatory Authority of Energy (RAE), Greece 2007-2009

Mr. Frowd provided consulting and software services to analyze various new market elements RAE was contemplating for the Wholesale Energy market in Greece. Specifically, Mr. Frowd deployed ProMaxLT™ to analyze the Real-Time Dispatch market (RTD) and the design of the Tertiary Reserve market in Greece.

California ISO 2004

Mr. Frowd developed a Must Offer Unit Commitment application in Java for the California Independent System Operator, using Mixed Integer Programming methodologies as the solution engine with a direct Java interface. He performed a detailed comparison between

the implemented MIP based market simulation results and the MIP-based solution results supplied by the CAISO market software vendor. He also performed testing and validation over several months of real-time market data. He performed an audit of the Real-Time Security Constrained Dispatch functional specifications with the associated FERC filing documents.

Rod Frowd Systems Pty Ltd

Independent consultant, 1993 - 2003

Mr. Rod Frowd provided consulting services to various organizations in the electric energy industry. Recent projects include an ICCP data link between Powerlink and QPTC, a PC-based Ancillary Services dispatch program for NEMMCO and bid price calculation program for the Hydro Electric Commission of Tasmania, a Lagrangian Relaxation Hydro Thermal Unit Commitment, a customized short-term hydro optimization package using Mixed Integer Linear Programming and a dynamic programming-based generation expansion program for use in generation planning for Queensland Electricity Commission. He developed a telephone network design optimization program for a telecommunications company. He also developed an advanced power distribution analysis and optimization package as part of a Distribution Management System.

EMCA, Inc., Minneapolis, MN.

1989-1993

Mr. Frowd was a consultant to power utilities in Energy Management System area. Performed EMS consulting for several utilities in the U.S. and Australia, including Requirements Studies, Specification Development, Project Management, Factory Acceptance testing and Field Commissioning. Customers include Houston Light and Power, Long Island Lighting Company, Orlando Utilities Commission, Cincinnati Gas and Electric, Seattle City Light and Queensland Electricity Commission. Also developed PC and work-station based power system analysis software. Also wrote short-term Hydro Optimization program for the Hydro Electric Commission of Tasmania. He also wrote short-term Hydro and Interchange Optimization for Swiss Rail using Mixed Integer Linear Programming.

EMPROS Systems International, Minneapolis, MN.

1986-1989

Mr. Frowd worked on several large EMS projects in the Network Analysis area. He managed the Network Analysis group performing development of State Estimator, Power Flow and Optimal Power Flow applications for several large utilities, including Pacific Gas and Electric, Houston Light and Power, Electricity Generating Authority of Thailand.

Queensland Electricity Commission, Brisbane, Australia

1981-1986

Mr. Frowd was a software leader for QEC Energy Management System project. Performed software development and testing in system, database and advanced applications areas and worked on Integrated Resource Planning models.

ESCA Corporation, Bellevue, WA.

1980-1981

Mr. Frowd was involved in several EPRI research projects in load modeling for transient stability studies and in development of EPRI stability program.

State Electricity Commission of Queensland, Brisbane, Australia

1977-1978

Mr. Frowd was a member of the Generation Planning group, and he performed software development in probabilistic production costing and load forecasting.

PROJECT HISTORY

2003-2011 – Lead Architect and developer of ECCO's Reliability and Market Analysis Software Platform

Mr. Frowd led the development, implementation and deployment of the reliability analysis and energy market simulations suite for ECCO International. He has also led the deployment of the ECCO's software platform, for various reliability and market simulation and analysis projects around the world.

2005 – Distribution Automatic Service Restoration

Mr. Frowd developed an application as part of a Distribution Management System to isolate faulted area and restore supply, in closed loop mode, within one minute, taking account of adjacent feeder loadings and capacities.

2003 to 2005 – California ISO Must Offer Unit Commitment

Under ECCO, Mr. Frowd developed an application in Java to optimally determine additional generation to add to the schedules to meet reliability and transmission constraints. This project used Mixed Integer Linear Programming using the CPLEX solution engine. Project included sensitivity calculations for zonal and local transmission constraints.

2003 – California ISO Real-Time SCED Audit

He performed a detailed technical audit of the SCED functional specifications against the corresponding FERC filing documents.

2000 to 2002 – CES Distribution Optimization Development Project

Lead developer for the CES Distribution Optimization product, to perform automatic voltage reduction, loss minimization and reconfiguration to avert overloads for a 3 phase power flow fully integrated with the CES Outage Management suite.

2001 to 2003 – Vector Energy Distribution Power Flow Project, New Zealand

Mr. Frowd was a project lead for the distribution power flow for CES International, a large scale implementation of 1 million bus model including sub-transmission network.

2000 – ICCP Data Link

He was a project manager for the installation of an ICCP data link from Powerlink to QPTC.

2000 – Bid Optimization – QPTC

He developed a bid optimization program using Linear Programming to ensure that QPTC's contract position is covered.

1998 to 2000 – CES Power Flow Development Project

Lead developer for the CES Power Flow product, for a 3 phase power flow fully integrated with the CES Outage Management suite.

1999 – NEMMCO Ancillary Services Dispatch

Consultant to IES participated in review of Ancillary Services dispatch and assignment of costs for NEMMCO.

1999 – Hydro Electric Corporation, Tasmania

Mr. Frowd developed linear programming model of the HECT hydro generation to determine bid prices for the National Electricity market.

1998 to 1999 – NEMMCO Ancillary Services Dispatch

Mr. Frowd developed a mixed integer linear programming model of the Queensland Ancillary Services market for use in real-time dispatch of Ancillary Services by NEMMCO at the National Control Center at Belmont.

1995 to 1996 – NAPACOR EMS Hydro Applications

Mr. Frowd developed and implemented the advanced hydro applications for the NAPACOR EMS project for the island of Mindanao.

1993 to 1996 – Hydro Electric Commission of Tasmania

Mr. Frowd developed and implemented the advanced hydro applications for the HECT EMS project in Hobart.

1992 – Swiss Rail Hydro Applications

Mr. Frowd developed the advanced hydro and resource scheduling applications for the Swiss Rail EMS project using Mixed Integer Linear Programming.

1986-1989 – Pacific Gas and Electric EMS Project

Mr. Frowd was the team leader for the advanced network analysis functions for the PG&E EMS project.

1988-1989 – Houston Light and Power EMS Project

Mr. Frowd was the manager for the advanced network analysis functions for the PG&E EMS project.

1981-1986 – Queensland Electricity Commission EMS Project

Mr. Frowd was the software leader of the QEC EMS project from project definition to successful field implementation. This project was the most successful EMS project in Australia, just recently retired after 14 years of service.

PUBLICATIONS

1. R.J. Frowd, R. Podmore, and M.Waldron, "Synthesis of Dynamic Load Models for Stability Studies", presented at IEEE PICA 1981.
2. R.J. Frowd, J. Giri, and R. Podmore, "Transient and Long-Term Dynamics Unified", presented at IEEE Summer Power Meeting, 1982.
3. R.J. Frowd and I.A. Hiskens, “A New Improved Algorithm for Fast Decoupled Load Flow, presented at 1985 IFAC Conference in Rio De Janeiro.
4. M. Piekutowski, T. Litwinowicz, and R.J. Frowd, "Optimal Short-Term Scheduling for a Large-Scale, Cascaded Hydro System”, IEEE Transactions on Power Systems, Vol. 9, No. 2, May 1994, pp 805-811.

5. M. Christoforidis, B. Awobamise, S. Tong, M Aganagic, R. J. Frowd, F. A. Rahimi, “Short-term Hydro Generation and Interchange Contract Scheduling for Swiss Rail”, IEEE Transactions on Power Systems, Vol. 11, No 1, February 1996, pp 287-294.
6. N. Tufedgzic, R.J. Frowd, W. Stadlin, “A Coordinated Approach For Real-Time Short-Term Hydro Scheduling”, IEEE Transactions on Power Systems, Volume 11, Issue 4, Nov. 1996 Page(s):1698 - 1704
7. Grubauer, W.; Underwood, R.; Telgenhoff, M.; Frowd, R., “Optimal hydro generation and interchange scheduling with flow-dependent channel constraints”, Energy Management and Power Delivery, 1995. Proceedings of EMPD '95., 1995 International Conference on,Volume 2, 21-23 Nov. 1995 Page(s):595 - 600 vol.2
8. Zhou, Q, Frowd, R., Papalexopoulos, A., Lamb, D., Ledesma, E., “Minimizing Market Operation Costs Using a Security-Constrained Unit Commitment Approach”. Presented at IEEE T&D Conference 2005, China.