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FIDO™

Fully Integrated Dispatch & Optimization (FIDO) Methods and Applications
Net Benefits Analysis for Energy Efficiency and Renewable Resources

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INTRODUCTION

In addition to the vertically integrated electric utility, a new market for integrated resource planning has formed as a result of restructured of electricity marketplaces, increasing renewable portfolio standards, and greenhouse gas emissions credits and trading. Tools like RETScreen® and HOMER are expanding micro-system analysis for renewable and demand-side technologies to a market rapidly approaching 100,000 users.[1,2] The vast majority of these users, however, cannot accurately assess avoided costs and emissions from grid-integration. The expense and complexity of leading commercial software applications limits their use to a few hundred utilities, regulatory agencies, and consulting entities. The lack of fully integrated analysis capability is a major detriment to a valid net benefits analysis. Measuring avoided emissions with system-averaged rates has been shown to be inaccurate and raises questions about the validity of simple conventions for emissions or financial analysis.[3]

FIDO simulates the hourly operation of utility-scale electric generation, incorporating the hour-by-hour performance of intermittent renewable power, demand-side technologies, and market power transactions (Figure 1). FIDO is not a substitution for the planning software employed by electric utilities and regulators, but offers a significant improvement over simple screening tools, which cannot capture the details of hourly production. FIDO simulates hourly unit commitment, allowing long-term grid-integrated analysis of intermittent technologies with greatly improved detail and accuracy, and providing a new opportunity for:

- Utility planners and regulators desiring improved technology screening.
- Energy efficiency program administrators evaluating planning alternatives.
- Renewable energy researchers requiring location specific net benefits analysis.
- Greenhouse gas market participants seeking accurate and defensible emissions analysis.
- Global manufacturers assessing life-cycle environmental impact from electricity generation.

FIDO is an ambitious research effort under ongoing development. Meier Engineering Research (MER) is seeking opportunities to advance this technology through studies performed in conjunction with utility planning models, and stand-alone analysis of individual projects and programs. This document provides background information, market description, and modeling methods.

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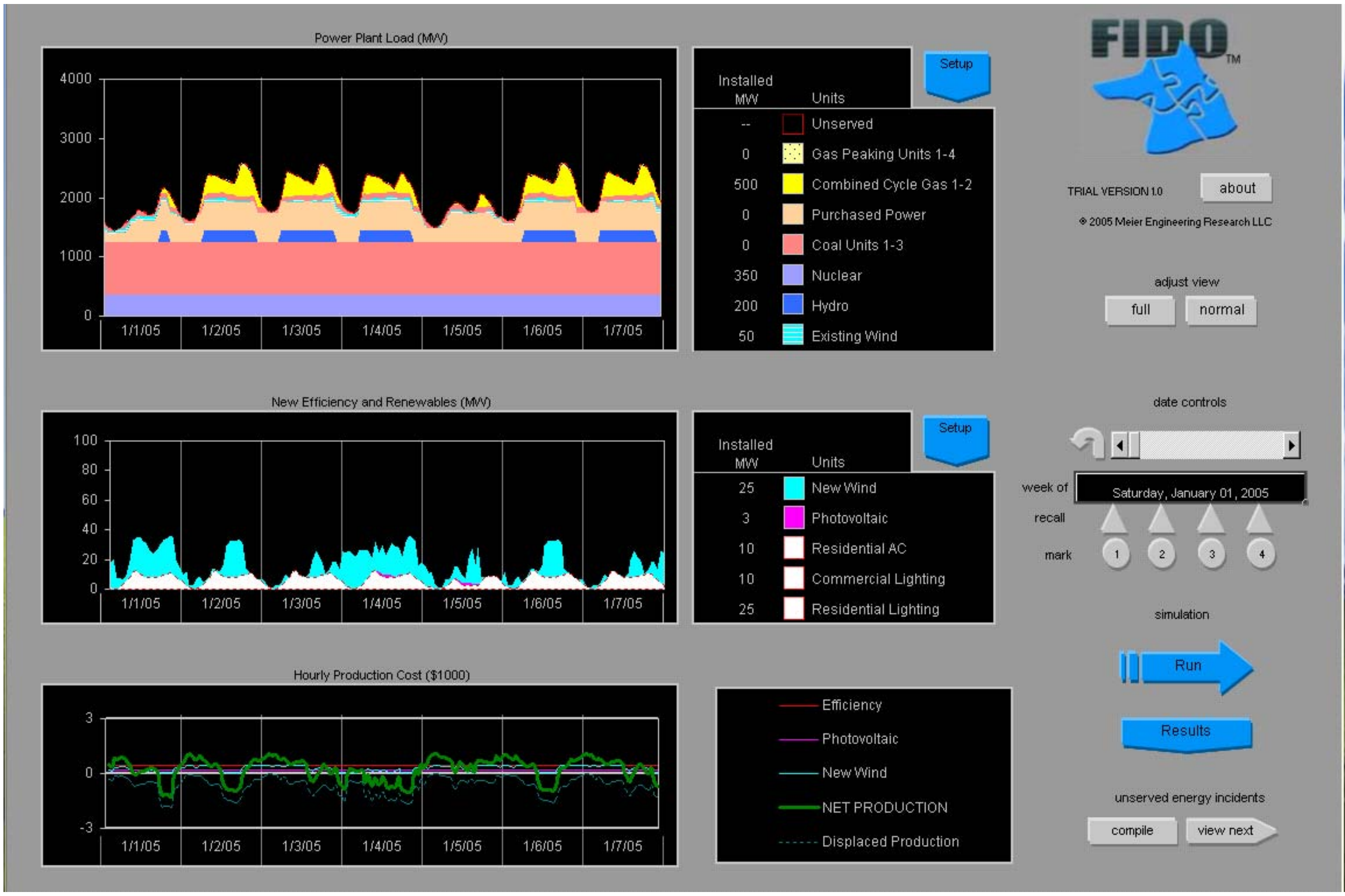

Figure 1. A FIDO Trial Version is currently available for evaluation by select organizations at www.merllc.com.

BACKGROUND

Electric utilities initially coupled detailed end-use forecasting models with detailed production costing models. These models were intended for stand-alone use, and their integration was an onerous process. In the 1980's a new class of "integrated" planning models substituted less-detailed analysis of both supply and demand side processes in a single software platform.[4] The current leading market providers include EnerPrise® Software (a.k.a. PROSYM®, MIDAS®) from Global Energy Decisions[5], AURORA® from E.P.I.S.[6], and Strategist® from New Energy Associates[7].

Maintaining state-of-the-art modeling applications in non-utility programs is rarely viable, with the requisite software license fees potentially ranging from $30,000 – 200,000 annually, in addition to considerable staff and consulting time.[8] Total U.S. utility, regulatory, and consulting entities with license to these technologies number in the low hundreds. Meanwhile, there is a significant and growing market gap for integrated analysis of renewable energy and demand side technologies, as evidenced by the exploding use of RETScreen® (60,000 users) and HOMER (6,000 users). While these programs are rapidly extending sophisticated production analysis for individual technologies, the vast majority of these users cannot accurately assess avoided costs and emissions when the individual technology is grid-integrated.

The lack of integrated analysis capability is a set-back for entities hoping to capitalize on small scale opportunities made increasingly possible by renewable portfolio standards in the U.S. and Kyoto Protocol mechanisms internationally. Avoided cost and emissions is one half of the net benefits equation, and crucial to understanding financial and emissions performance. Measuring avoided emissions with system-averaged rates has been shown to be inaccurate and raises questions about the validity of non-integrated analysis for emissions or financial analysis.[3]

MODELING FRAMEWORK

It is important to understand the objective of this model and its relationship to the existing commercial modeling framework. Electric generation simulations, while nebulous, may be roughly subdivided into two categories: 1) long-term models used for strategic planning, and 2) short-term models used for energy trading, risk analysis, and unit scheduling.

The short-term models evaluate power plant dispatch and market interactions in small time-steps, typically from several minutes to a few hours. A common application is to optimally schedule the anticipated power plant operation for a period of a few days to a week. Predicting short-term market prices, optimizing profitability of individual units, and minimizing risk is a new application in restructured markets. Optimal unit commitment is no small endeavor and relies on decades of computational research.[9] In practice this involves evaluating every conceivable combination of generating units and market interactions, while incorporating operational constraints, such as startup and cycling costs, ramping restrictions, minimum up and down time, transmission constraints, spinning reserves, and energy limits.[10,11,12]

The problem of finding optimal solutions is a balancing act between accurately simulating the real world, and providing enough simplification and constraints to allow a mathematical solution in reasonable time. As described by Larson, “the optimum solution of real sized problems generally cannot be found within reasonable computational time by techniques of operations research.”[13] Still, commercial applications provide adequate solutions to the short-term market analysis and scheduling using state of the art computational science. Too much detail is retained in the short term models, however, to allow the same methods to solve the long-term generation expansion optimization.

The models used for long term strategic planning must make major simplifications in order to create a solvable problem. The hourly chronological load and subsequent operational details are replaced by simple estimates of load, as described by a load duration curve (LDC). The load duration curve is generated by sorting chronological load from highest to lowest, thereby creating a curve representing system load typically for a year, season, or month. The area under this curve is the total energy requirement and individual generator contributions may be solved very quickly using simple integration. Significant detail is lost with this simplification, in particular the generator operations required to meet variable loads.[14] Several manipulations have been proposed to the LDC method in effort to better predict operational realities such as planned and forced outages, cycling costs, and DSM impacts.[15,16] Commercial LDC models vary in sophistication from simple deterministic models, to probabilistic simulations and dynamic/linear programming optimization applications.[8] In general, the accuracy of any LDC model can be greatly improved when calibrated against a detailed chronological production model.

FIDO does not seek optimal solutions for either the short-term unit scheduling or utility-scale generation expansion. These problems will continue to be solved with existing market solutions. Instead, the goal of FIDO is to provide a good simulation of hourly unit commitment, so that the long-term grid integrated impacts of intermittent technologies or micro-systems can be evaluated with greatly improved detail and accuracy. Once the long-term generation scenarios have been established for the macro system, FIDO provides a means for utility planners, energy efficient program administrators, or renewable researchers to evaluate the cost and benefits of their micro-system, and to rapidly test planning alternatives. Optimal design of a micro system is a viable endeavor as described below.

MODELING METHODS

FIDO allows the user to evaluate micro-system performance within a long-term hourly simulation of a utility-scale electric system. Details of the micro-system are provided by programs such as HOMER, RETScreen, or custom spreadsheet analysis. Creating a simulation of a utility-scale system requires a demand forecast, data for existing generating units, and a schedule and characteristics for planned capacity additions. In the U.S., FERC reporting provides utility specific data on loads, generating units, and proposed additions. Some of FIDO's internal functions (e.g., demand forecast, market price forecast) are typically generated by stand-alone models in a utility environment. Such modeling results may be incorporated when available, however, FIDO can also provide a reasonable approximation in their absence.

Dispatch - FIDO uses an hourly load data for a recent, typical historic year as the baseline of its demand forecast. The typical baseline load is "stretched" to simulate future load growth. FIDO constructs the chronological hourly load for a week, efficiently dispatching the available resources, and repeats the process for each week of the simulation. Energy efficient resources are modeled as equivalent generating units and are dispatched first.[17] Hydroelectric capacity is dispatched to run during the highest load periods of each week. Remaining units are dispatched in ascending order of their marginal production cost.

Market Interaction - Power purchase decisions are made based on a variable hourly market. The simulation includes limits on inter-regional import capacity, and variable changes in this limit as a result of transmission constraint. Purchased power is further constrained by modeling a realistic requirement for a "local" plant to follow load. Because displaced generation and associated emissions are occurring from this local plant, the uncertainty of fuel source from purchased power does not alter emissions estimates. The goal of ongoing research is to continuously improve unit commitment and market power interactions to provide as accurate a simulation as possible.

Emissions - Emissions are estimated based on the fuel-specific emission rates. Emission rates are adjusted to account for changing thermal efficiency using heat rate curves for each plant. The minor fluctuations in emission rate caused by heat rate effects are visible in Figure 2. The cost and performance of air pollution control equipment may be implemented based on utility-specific data or generic guidance.

Net Benefits Analysis - FIDO calculates avoided production cost and emissions by running the simulation both with and without the micro-system technologies. Figure 2 illustrates how emission reductions can be attributed to a demand-side end-use technology. The load displaced by 1MW of installed residential air conditioning is overlain on the center plot. Emissions reductions (Bottom Plot) can be calculated by multiplying the marginal emission rate and the displaced load (Center Plot). Careful examination of the Bottom Plot reveals how the emission reductions are a combination of both the marginal emission rate and the end-use load shape.

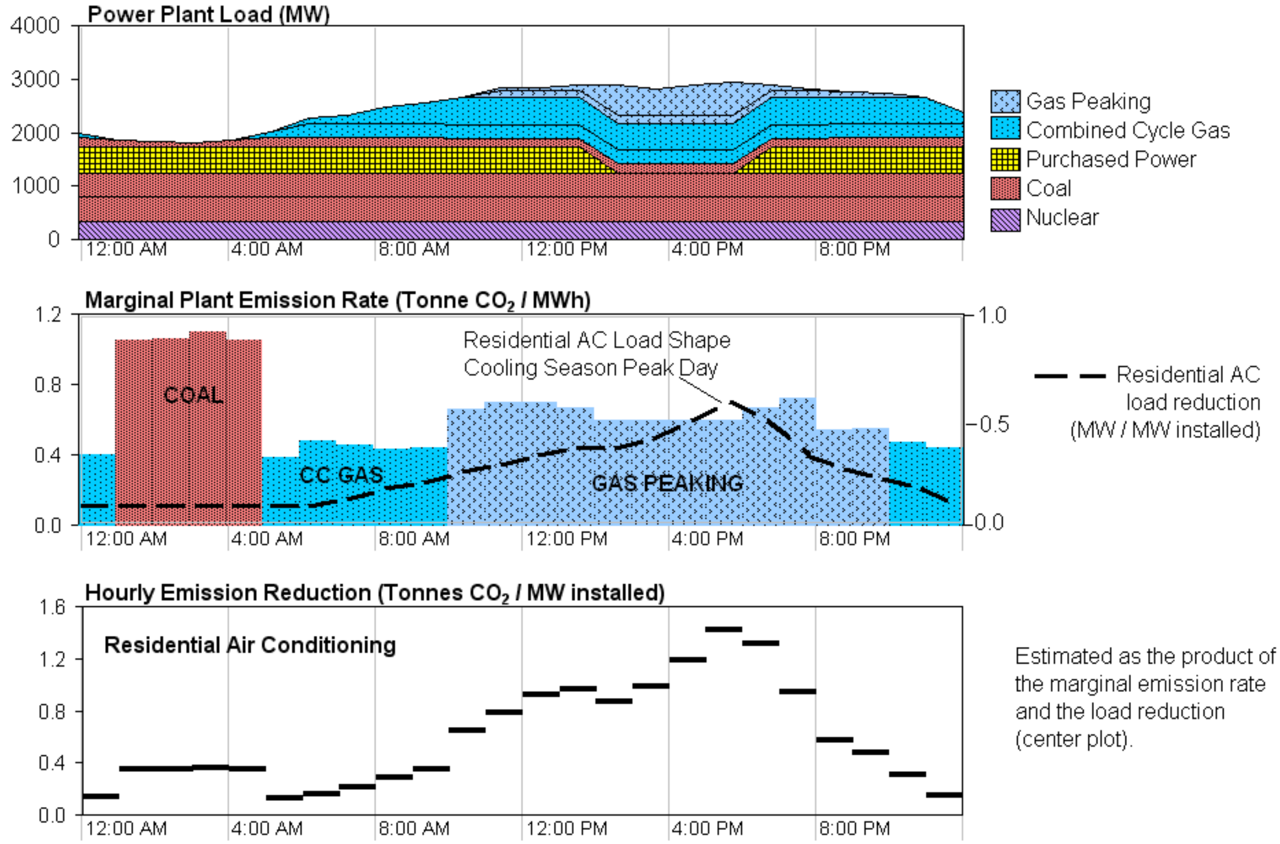

Figure 2. FIDO Modeling Illustration – Hourly CO2 Reductions Achieved per MW of High Efficiency Residential Air Conditioning Installed. [3]

Micro-system Optimization - Once adequate confidence in the supply-side simulation is obtained, micro-system alternatives may be evaluated using optimization algorithms. For example, an energy efficient program may consist of several technology markets with very different characteristics. A common debate is whether spending is better directed towards lower-cost and fast-implementing technologies (e.g. lighting), or more expensive, longer-lived technologies with high peak demand coincidence (e.g., air conditioning). The best performing portfolio could be determined using a cost-minimizing optimization. As described previously, too much detail is retained in the hourly modeling to perform this particular search in reasonable computational time. Therefore, this example would require LDC modeling, calibrated with FIDO's hourly production simulation. Because FIDO is a Microsoft Excel application, optimization may be performed with either Excel's solver, or third-party spreadsheet optimization add-ins.

CONCLUSIONS

There is significant and growing demand for integrated analysis of renewable energy and demand side technologies. The lack of truly integrated analysis for micro-systems is a major detriment to a valid net benefits analysis. Measuring avoided emissions with system-averaged rates has been shown to be inaccurate and raises questions about the validity of non-integrated analysis for emissions or financial analysis. By providing an hourly simulation of utility-scale electric generation, FIDO offers a significant improvement over simple screening tools, enabling long-term grid-integrated analysis with greatly improved detail and accuracy.

ABOUT MER

Meier Engineering Research (MER) provides energy systems modeling for research, education, and outreach. MER's primary software application, Energy ED, is a virtual planning simulation for electricity generation expansion.[18] This exercise allows electric utilities, regulators, and energy professionals to engage stakeholders and the public in discussing scenarios, alternatives, and trade-offs. FIDO was initially developed as a means to ensure accuracy in Energy ED by comparison and calibration with more rigorous analysis. Because of its ability to perform integrated hourly analysis, FIDO has significant potential to provide net benefit analysis with a degree of detail previously unachievable without state of the art production software. Paul Meier, Principal of MER, has provided energy and environmental expertise to industry, public interest, and government for over a decade and is a two-time recipient of the General Motors Environmental Excellence Award for original research on greenhouse gas mitigation. Meier received his Ph.D. from the Gaylord Nelson Institute of Environmental Studies at the University of Wisconsin-Madison. He received his B.S. and M.S. degrees in environmental engineering from Purdue University and Clemson University respectively.

REFERENCES

[1] HOMER Optimization Model for Distributed Power. National Renewable Energy Laboratory. http://www.nrel.gov/homer/.

[2] RETScreen International Clean Energy Project Analysis Software. Natural Resources Canada. http://www.retscreen.net/.

[3] P.J. Meier, J. Erickson, J. Mapp. In Press. "Measuring Emission Benefits with Hourly Production Models - Why Simple Estimates of Emission Reductions May Be Wrong" *2005 Proceedings of the International Energy Program Evaluation Conference (IEPEC).*

[4] J.H. Eto. 1990. "An Overview of Analysis Tools For Integrated Resource Planning" *Energy* 15 (11) 969-977.

[5] Global Energy Decisions. http://www.globalenergy.com/enerprise.asp.

[6] E.P.I.S. Inc., http://www.epis.com/.

[7] New Energy Associates, A Siemens Company. http://www.newenergyassoc.com/index.html.

[8] e7. 2000. Guidelines for the Pooling of Resources and the Interconnection of Electric Power Systems (RECI). www.e7.org.

[9] G.B. Sheble and G.M. Fahd. 1994. "Unit Commitment Literature Synopsis." *IEEE Transactions on Power Systems* 9(1) 128-135.

[10] B. Lu. M. Shahidehpour. 2005. "Unit Commitment With Flexible Generating Units." *IEEE Transactions on Power Systems* (0885-8950) 1-13.

[11] J. Valenzuela. M. Mazumdar. 2001. "Making Unit Commitment Decisions when Electricity is traded at Spot Market Prices." *IEEE(* 0-7803-6672-7/01) 1509-1512.

[12] C. Wang. S.M. Shahidehpour. 1994. "Ramp-Rate Limits in Unit Commitment and Economic Dispatch Incorporating Rotor Fatigue Effect." *IEEE Transactions on Power Systems* 9(3)1539-1545.

[13] T.J. Larsen. et. al. 2001. Sequential Timestep Unit Commitment." *IEEE* (0-7803-6672-7/01) 1524-1529.

[14] S. Hadley. E, Hirst. 1998. "ORCED: A Model to Simulate the Operations and Costs of Bulk-Power Market." Oak Ridge National Laboratory ORNL/CON-464.

[15] D.T. Gardner. 2000. "Efficient Formulation of Electric Utility Resource Planning Models." *Journal of the Operational Research Society* (51) 231-236.

[16] A.S. Malik. 2001. "Modelling and Economic Analysis of DSM Programs in Generation Planning." *Electrical Power and Energy Systems* 23(2001) 413-419.

[17] A.S. Malik. 1998. "Dynamic Generating Costs in DSM Planning." Energy 24(1998) 1-8.

[18] Energy ED Software. www.energyEDsoftware.com.