Economic dispatch References

Presentations

R. Baldick, “Economic Dispatch and ERCOT: Presentation to the Texas House Regulated Industries Committee, April 28, 2004.
http://www.ksg.harvard.edu/hepg/Papers/Baldick_ec.dispatch.ERCOT.28.apr.04.pdf

J.D. Chandley, “RTO Basics: What RTOs Do and How They Support Retail Choice”, presentation to Illinois Commerce Commission, Chicago, June 22, 2004.
http://www.icc.illinois.gov/ec/docs/040729ecPostProcureRTO.pdf

V. Petrov, J. Nicolaisen, “A Simple Unit Commitment Problem”, presentation to NSF, Oct 18, 1999
http://www.econ.iastate.edu/tesfatsi/unitcom.ppt

Non-technical

E. Hirst, “Real-time Balancing Operations and Markets: Key to Competitive Wholesale Electricity Markets”, report to Edison Electric Institute and Project for Sustainable FERC Energy Policy, April 2001. (in particular see Chapter 2)

W. W. Hogan, “A Competitive Electricity Market Model”, report for HEPG, October 9, 1993. (see especially pp. 84-97)

W. W. Hogan, “Contract Networks for Electric Power Transmission,” Journal of Regulatory Economics, pp 211-242, 1992.

T.J. Overbye, “Power system simulation: understanding small- and large-system operations,” Power and Energy Magazine, IEEE, Vol. 2, Issue 1, pp 20-30, Jan-Feb 2004.
Abstract
This article is the fourth in a series based on the IEEE PES Power System Basics for Business Professionals tutorial. The article provides a summary of the presentation given in the course on power system operations, building on the foundation provided by the "Electricity Basics" portion of the course. Simulation software is used throughout the article to explain many of the concepts associated with power system operations. The focus of this article is o the operation of these large, interconnected grids.

S. Stoft, Power System Economics, John Wiley/IEEE, New York, February 2002.

R. Thomson, “Economic Dispatch and a Competitive Electricity Market: A Comparative Review”, for Harvard Electricity Policy Group, January 8, 1995.

Technical

K. Abdul-Rahman, M. Shahidehpour,M.Aganagic, S. Mokhtari, “A Practical Resource Scheduling with OPF Constraints,” IEEE Trans. Power Syst., Vol. 11, No. 1, Pp. 254–259, Feb. 1996.
Abstract
This paper presents an efficient approach to short term resource scheduling based on the augmented Lagrangian relaxation method. The problem is divided into two stages, the commitment stage and the constrained economic dispatch stage. The proposed mathematical model incorporates power flow (OPF) constraints in the unit commitment stage. By OPF constraints, we refer to the relevant active power

constraints that are incorporated in the constrained economic dispatch stage (i.e. transmission capacity constraints, fuel and various regulated emission requirements). The inclusion of OPF constraints in the commitment stage will improve the feasibility of the constrained economic dispatch solution. Other unit commitment constraints such as spinning and operating reserve requirements, power balance as well as other relevant local constraints (i.e. unit ramping rates, upper and lower generation limits, minimum up and down times) are taken into account in the proposed model. As we deal with a larger number of constraints, a more rigorous method is introduced for updating Lagrange multipliers to improve the solution convergence. A software package which addresses energy management systems requirements is developed and tested

M. Aganagic, B.Awobamise, G. Raina, A.I. McCartney, "Economic dispatch with generation contingency constraints" IEEE Transactions on Power Systems, Vol. 12, Issue 3, pp 1229-1236, Aug 1997.

Abstract
This paper presents a new model of the generation contingency constrained economic dispatch problem and proposes a method for its solution. The operating policy of Northern Ireland Electricity was the basis for the formulation, and software was implemented to support it. Since the Northern Ireland Electricity power system operates in relative isolation, the operating security criteria are rather stringent. In particular, it is required that loss of generation of any generating unit in the system must be covered by fast, 3 or 30 second generation reserves on other units in the system. The fast response unit reserve capabilities are represented by concave curves. The solution method is based a nonlinear version of Dantzig-Wolfe decomposition principle. Numerical results are presented.

N. Alguacil, A. Conejo, "Multiperiod Optimal Power Flow Using Benders Decomposition," IEEE Trans. Power Syst., Vol. 15, No. 1, Pp. 196–201, Feb. 2000.

Abstract
This paper addresses a multiperiod optimal power flow, properly modeling the start-up and shut-down of thermal units, the transmission network in terms of line capacity limits and line losses, and the constraints of hydroelectric plants integrated in river systems. The generalized Benders decomposition is used to solve this large-scale multiperiod problem. Spot prices are obtained as a byproduct of the decomposition procedure. A realistic case study based on the electric energy system of mainland Spain is analyzed and the results obtained are reported.

S. Asgarpoor, S.K. Panarelli, "Expected Cost Penalty due to Deviation from Economic Dispatch for interconnected power systems", IEEE Transactions on Power Systems, Vol. 10, Issue 1, pp. 441-447, Feb 1995.

Abstract
This paper introduces and evaluates a new index called "Expected Cost Penalty due to Deviation from the Economic Dispatch" (EPDED) for interconnected power systems. This index represents the cost penalties associated with uncertainties such as random failure of generating units, load growth, and fuel costs in interconnected power systems. The significance of this index is that it represents common events such as operating problems that can be observed over short periods (e.g., one or two years) rather than the rare events such as load curtailment which is currently used for reliability evaluation of power systems. This paper presents two techniques to evaluate this index. Monte-Carlo simulation and a tree structured state enumeration. System studies are performed to determine the variation of expected cost penalty with respect to changes in load values and probability of failure of generating units.

B.H. Chowdhury, S. Rahman, "A Review of Recent Advances in Economic Dispatch", IEEE Transactions on Power Systems, Vol. 5, No. 4, Nov. 1990.

Abstract
A survey is presented of papers and reports that address various aspects of economic dispatch. The time period considered is 1977-88. Four related areas of economic dispatch are identified and papers published in the general areas of economic dispatch are classified into these. These areas are: optimal power flow,

economic dispatch in relation to AGC, dynamic dispatch, and economic dispatch with nonconventional generation sources.

J. K. Delson M. Shahidehpour, “Linear Programming Applications To Power System Economics, Planning, And Operations,” IEEE Transactions on Power Systems, Vol. 7, No. 3, Pp. 1155–1163, Aug. 1992.
Abstract
The authors discuss power system engineering applications of linear programming and indicate the potential for its future use. Applications are outlined in three areas: generation scheduling, loss minimization through allocation of reactive power supply, and planning of capital investments in generation equipment. It is recommended that power system planning models should incorporate financial flows with the linear programming approach to capital budgeting originally formulated in 1963 by H.M. Weingartner. The need for such an approach is illustrated with examples of how capital market conditions can upset the type of engineering economic decision making currently used in planning models. The Lagrangian relaxation method, which can extend computational feasibility for linear and integer programming, is also described.

Y. Fu, M. Shahidehpour, Z. Li, “Security-Constrained Unit Commitment With AC Constraints”, IEEE Transactions On Power Systems, Vol. 20, No. 3, August 2005.
Abstract
In a restructured power market, the independent system operator (ISO) executes the security-constrained unit commitment (SCUC) program to plan a secure and economical hourly generation schedule for the day-ahead market. This paper introduces an efficient SCUC approach with ac constraints that obtains the minimum system operating cost while maintaining the security of power systems. The proposed approach applies the Benders decomposition for separating the unit commitment (UC) in the master problem from the network security check in subproblems. The master problem applies the augmented Lagrangian relaxation (LR) method and dynamic programming (DP) to solve UC. The subproblem checks ac network security constraints for the UC solution to determine whether a converged and secure ac power flow can be obtained. If any network violations arise, corresponding Benders cuts will be formed and added to the master problem for solving the next iteration of UC. The iterative process will continue until ac violations are eliminated and a converged optimal solution is found. In this paper, a six-bus system and the IEEE 118–bus system with 54 units are analyzed to exhibit the effectiveness of the proposed approach.

Han, X.S. Gooi, H.B. Kirschen, D.S. , “Dynamic economic dispatch: feasible and optimal solutions”, IEEE Transactions on Power Systems, Vol. 16, No. 1, pp 22-28, Feb 2001.
Abstract
Dynamic economic dispatch is an extension of the conventional economic dispatch problem that takes into consideration the limits on the ramp rate of the generating units. This paper examines the factors that affect the feasibility and optimality of solutions to this problem. It proposes two new solution methods. The first is guaranteed to find a feasible solution even when the load profile is nonmonotonic. The second is an efficient technique for funding the optimal solution. The results obtained with these methods are compared with those obtained using previously published methods.

Hobbs, B. F., Rothkopf, M. H., O'Neill, R. P., And Chao, H-P. (Eds.), The Next Generation Of Electric Power Unit Commitment Models, Kluwer Academic Press, 2001. (in particular see B. F. Hobbs, W.R. Stewart, Jr., R. E. Bixby, M. H. Rothkopf, R. P. O’Neill, H-P. Chao, “Why This Book?: New Capabilities And New Needs For Unit Commitment Modeling,” Pp. 1-14.)

W. W. Hogan, B. J. Ring, “On Minimum Uplift Pricing For Electricity Markets,” Electricity Policy Group, Harvard University, March, 2003.
Abstract
Optimality and equilibrium principles serve to characterize pricing and settlement rules in electricity market designs. Practical electricity markets include both approximations and nonconvexities that deviate from the pure case of the simple equilibrium pricing model. Recent results on equilibrium price

characterizations for a class of nonconvex optimization problems provide new insight of direct relevance to electricity markets. The day-ahead electricity market application illustrates the key innovation in equilibrium pricing. A minimum-uplift pricing approach provides a related theoretical framework that is closer to actual practice.

R. Orans, A. Olson, C. Opatrny “Market Power Mitigation and Energy-Limited Resources”, The Electricity Journal, Vol. 16, No. 2, March 2003.
Abstract
FERC’s Standard Market Design takes aim at the problem of withholding by proposing automated mitigation procedures (AMP) as a tool to prevent the exercise of market power. However, only "light-handed" AMP with bid caps based on opportunity costs and no must-offer requirement will result in efficient operations of energy-limited resources.

N. P. Padhy, “Unit Commitment—A Bibliographical Survey,” IEEE Transactions on Power Systems, Vol. 19, No. 2, May 2004.
Abstract
With the fast-paced changing technologies in the power industry, new power references addressing new technologies are coming to the market. So there is an urgent need to keep track of international experiences and activities taking place in the field of modern unit-commitment (UC) problem. This paper gives a bibliographical survey, mathematical formulations, and general backgrounds of research and developments in the field of UC problem for past 35 years based on more than 150 published articles. The collected literature has been divided into many sections, so that new researchers do not face any difficulty in carrying out research in the area of next-generation UC problem under both the regulated and deregulated power industry.

Ramanathan, R., “Emission Constrained Economic Dispatch”, IEEE Transactions on Power Systems, Nov 1994, Volume: 9, Issue: 4
Abstract
This paper presents a methodology to include emission constraints in classical economic dispatch (ED), which contains an efficient weights estimation technique. Also, a partial closed form technique is presented to implement the emission constrained economic dispatch (ECED). A simple technique is proposed to identify the binding constraints. The methods proposed do not need any user-supplied tuning or conversion factors. Dispatch quality is not compromised, and any practical sized problem can be solved efficiently. The proposed methods have rapid and consistent convergence to the Kuhn-Tucker optimality conditions. Different methods of including emissions as well as their advantages and disadvantages are discussed. Sample test results are presented. The two proposed methodologies have potential for on-line implementation.

Ross, D W, “Dynamic Economic Dispatch of Generation”, IEEE Trans. Power Appar. and Sys., Vol. PAS-99, No. 6, Pp. 2060-2068. 1980.

M. Shahidehpour, H. Yamin, Z. Y. Li, Market Operations in Electric Power Systems. New York: Wiley, 2002.

M. Shahidehpour, V. Ramesh, “Nonlinear Programming Algorithms And Decomposition Strategies For OPF,” In IEEE/PES Tutorial On Optimal Power Flow. Piscataway, NJ: IEEE Press, 1996.

C. Silva, B. F. Wollenberg, C. Z. Zheng, “Application of mechanism design to electric power markets (Republished)**”,** IEEE Transactions on Power Systems, Vol. 16, Issue 4, pp. 862-869, Nov 2001.
Abstract
As competition is introduced across the electric power industry around the world, market design for the industry is urgently needed to shape its future structure and performance. When generator companies

compete with one another in a deregulated market, they may not be willing to share the information needed to perform an economic dispatch of the generation. Using game theory, this paper designs a new mechanism that achieves efficiency (economic dispatch) in spite of this information problem. In this mechanism, when each company acts in the best of its own interests, the outcome is efficient. The paper demonstrates the merits of the mechanism by simulations including the IEEE 14-bus case.

S. Takriti and J. R. Birge, "Using Integer Programming to Refine Lagrangian- Based Unit Commitment Solutions," IEEE Trans. Power Syst., Vol. 15, No. 1, Pp. 151–156, Feb. 2000.

Abstract
The authors develop a technique for refining the unit commitment obtained from solving the Lagrangian. Their model is a computer program with nonlinear constraints. It can be solved to optimality using the branch-and-bound technique. Numerical results indicate a significant improvement in the quality of the solution obtained

C. L. Tseng, S. S. Oren, C. S. Cheng, C. A. Li, A. J. Svoboda, And R. B. Johnson, "A Transmission-Constrained Unit Commitment Method in Power System Scheduling," Decision Support Systems, Vol. 24, 1999, Pp. 297-310.

Abstract
This paper presents a transmission-constrained unit commitment method using a Lagrangian relaxation approach. Based on a DC power flow model, the transmission constraints are formulated as linear constraints. The transmission constraints, as well as the demand and spinning reserve constraints, are relaxed by attaching Lagrange multipliers. A three-phase algorithmic scheme is devised including dual optimization, a feasibility phase and unit decommitment. A large-scale test problem with more than 2200 buses and 2500 transmission lines is tested along with other test problems.

C. Wang, S.M. Shahidehpour, "Effects of ramp-rate limits on unit commitment and economic dispatch", IEEE Transactions on Power Systems, Vol. 8, Issue 3, pp 1341-1350, Aug 1993.

Abstract
The authors propose an algorithm to consider the ramp characteristics in starting up and shutting down the generating units as well as increasing and decreasing power generation. They consider the inclusion of ramping constraints in both unit commitment and economic dispatch. Since implementing ramp-rate constraints is a dynamic process, dynamic programming (DP) is a proper tool to treat this problem. To overcome the computational expense which is the main drawback of DP, this study initially employs artificial intelligence techniques to produce a unit commitment schedule which satisfies all system and unit operation constraints except unit ramp-rate limits. Then, a dynamic procedure is used to consider the ramp properties as units are started up and shut down. According to this adjustment, maximum generating capabilities of units will change the unit operation status instead of following a step function. Finally, a dynamic dispatch procedure is adopted to obtain a suitable power allocation which incorporates the unit generating capability information given by unit commitment and unit ramping constraints, as well as the economical considerations. Two examples are presented to demonstrate the efficiency of the method.

W. G. Wood, "Spinning Reserve Constrained Static and Dynamic Economic Dispatch", IEEE Trans. Power Appar. and Sys. Vol. PAS-101, No. 2, Pp. 381-388. 1982.

F. Wu, P. Varaiya, P. Spiller, S. Oren, "Folk Theorems of Transmission Access: Proofs and Counterexamples", Journal of Regulatory Economics, 10:5-23, 1996.

Abstract
Nodal prices, congestion revenues, transmission capacity rights, and compensation for wire ownership are key concepts used to formulate claims about proposals to organize competitive and open transmission access. Underlying those clasim are implicit assertions (folk theorems) concerning the regulation of transmission access, the determination of power flows, propertied of economic dispatch, and the operations of competitive nodal markets for power. The paper has two objectives. We first formulate these folk theorems as explicit mathematical assertions. We then prove that some of these assertions are true, and we present counter examples to other assertions. The counterexamples are interesting because they negate plausible propositions, including: (1) uncongested lines of not receive congestion rents (defined through

node price differences); (2) nodal prices clear markets for power only if the allocation is efficient; (3) in an efficient allocation power can only flow from nodes with lower prices to nodes with higher prices; (4) strengthening transmission lines or building additional lines increases transmission capacity (5) transmission capacity rights are compatible with an economically efficient dispatch.

Engineering Reference

J. D. Glover, M. S. Sarma, Power System Analysis and Design, 3rd Edition, Pacific Grove: Brooks/Cole, 2002. (in particular see pp. 525-538)

A. J. Wood, B. F. Wollenberg, Power Generation, Operation And Control. New York: Wiley, 1984.