A Synergistic Combination of Surrogate Lagrangian Relaxation and Branch-and-Cut for MIP Problems in Power Systems

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Abstract: Mixed-integer programming problems are prevalent in power systems. Historically, Lagrangian relaxation and subgradient methods were used to solve such problems by exploiting separability through relaxing coupling constraints and decomposing relaxed problems into subproblems. Although subgradient methods have been widely used to update multipliers, they require the relaxed problem to be fully optimized, and this can be computationally expensive. Moreover, convergence can be slow because multipliers often zigzag across "ridges" of the dual function. The recent trend is to solve these problems by using the branch-and-cut method that exploits problem linearity. However, complex problems such as stochastic unit commitment or even the deterministic version with combined cycle units can pose major computational challenges. The reason is that cuts that define a convex hull, referred to as "facet-defining" or "strong" cuts, are problem-dependent and may be difficult to obtain. Complex transitions among combined cycle states associated with one unit, for example, are treated as global constraints, and affect the entire problem. Very recently, we developed the Surrogate Lagrangian Relaxation method where a proper direction to update multipliers can be obtained without optimally solving all subproblems with much reduced computational effort and zigzagging. More importantly, convergence to the optimum does not require the knowledge of the optimal dual value. This was achieved with a constructive process in which distances between Lagrange multipliers at consecutive iterations decrease, and as a result, multipliers converge to a unique limit. The decrease cannot be too large to avoid premature termination of the iterative updating process. To enable an efficient exploitation of separability as well as linearity, surrogate Lagrangian relaxation and branch-and-cut are synergistically combined where surrogate Lagrangian relaxation is used to decompose a problem into subproblems by relaxing coupling constraints, and each subproblem is solved by using branch-and-cut. After decomposition, constraints associated with a subproblem are handled locally and no longer affect the entire problem. Furthermore, effective cuts for individual subproblems can be obtained easier than for the original problem. Numerical results on unit commitment with combined cycles demonstrated that the new approach is computationally efficient. The approach thus laid the foundation and opens up a new direction for optimizing MIP problems in power systems and beyond.

Bio Sketch. Peter B. Luh received his B.S. from National Taiwan University, M.S. from M.I.T., and Ph.D. from Harvard University. He has been with the University of Connecticut since 1980, and currently is the SNET Professor of Communications & Information Technologies. He was the Head of the Department of Electrical and Computer Engineering from 2006 to 2009. He is also a member of the Chair Professors Group, Center for Intelligent and Networked Systems (CFINS) in the Department of Automation, Tsinghua University, Beijing, China. Professor Luh is a Fellow of IEEE. He was the VP of Publications of RAS (2008-2011), the founding Editor-in-Chief of the IEEE Transactions on Automation Science and Engineering (2003-2007), and the Editor-in-Chief of IEEE Transactions on Robotics and Automation (1999-2003). He received IEEE Robotics and Automation Society 2013 Pioneer Award for his pioneering contributions to the development of near-optimal and efficient planning, scheduling, and coordination methodologies for manufacturing and power systems. His research interests include Smart Power Systems – smart grid, design of auction methods for electricity markets, robust renewable (wind and solar) integration to the grid, and electricity load and price forecasting; Intelligent Manufacturing Systems – planning, scheduling, and coordination of design, manufacturing, and service activities; Smart and Green Buildings and Eco Communities – optimized energy management, HVAC fault detection and diagnosis, emergency crowd guidance, and eco communities.