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Decomposing Loosely Coupled Mixed-Integer Programs for Optimal Microgrid Design

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Alex Zolan is a Ph.D. candidate in the Graduate Program in Operations Research and Industrial Engineering at the University of Texas at Austin. He has a B.S. in systems engineering and a B.S. in economics from the University of Pennsylvania, an M.A. in mathematics from Western Connecticut State University, and an M.S. in operations research and industrial engineering from the University of Texas at Austin. His research has covered applications including power cycle reliability in concentrating solar power plants, microgrid design, and security and risk assessment for nuclear power plants. His research interests include stochastic optimization and its interface with simulation, as well as simulation of energy systems.

Abstract:

The United States military installs forward operating bases (FOBs) to serve as protected locations from which to project and sustain combat operations in remote regions. FOBs must produce electric power without a grid connection. While these installations commonly use individual diesel generators attached to each load, microgrids that use a combination of diesel generators, photovoltaic systems and batteries are emerging as a distributed energy system that meets the requirements of a FOB in a safer, less costly and more environmentally friendly manner. We present a model that seeks the minimum-cost microgrid design and ideal dispatched power to support a FOB for a year-long time horizon with hourly fidelity under a detailed battery model. The resulting mixed-integer nonlinear program (MINLP) is intractable with commercial solvers but loosely coupled with respect to time. A mixed-integer linear program (MIP) approximates the model, and a partitioning scheme reduces the error associated with the linearization of bilinear terms. We introduce a novel policy for loosely coupled MIPs in which the system reverts to the same conditions at regular intervals; this separates the year-long problem into smaller subproblems that can be solved in parallel to provide upper and lower bounds on the model's optimal objective function value. This method allows us to obtain solutions within 5% of optimality in at most 10 minutes across a collection of 14 MIP instances from the literature, as opposed to about three hours with a commercial solver. We also obtain solutions to the MINLP instances within 5% of optimality within 30 minutes, and solve a stochastic optimization model under photovoltaic and load uncertainty. The optimized designs exhibit fuel savings of up to 30% compared to designs with only diesel generators.

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