Determining optimal design and operation of mixed-device energy systems

July 26 2012, BY GAIL PIEPER

(Phys.org) -- Researchers in the Mathematics and Computer Science Division at Argonne National Laboratory, in collaboration with colleagues at the Colorado School of Mines, have developed an optimization model that makes it easy to design and operate local power generation systems at minimal environmental and economic cost.

These systems supply power on-site using both nonrenewable, always available technologies, such as fuel cells, and renewable, weather-dependent technologies, such as wind turbines. When integrated with heat exchangers and solar turbine collectors, the on-site systems can also supply some of a building's cooling and heating demands.

"Distributed generation technologies offer the potential to supply on-site heat and power at a lower cost than traditional, centralized generation systems, but they have not been widely implemented, in part because of a lack of understanding about how to effectively configure and operate them," said Sven Leyffer, a computational mathematician at Argonne. "The model we've developed makes it easier for building owners to explore the economic impact of adding DG technologies."

Creating the optimization model itself, however, presented numerous challenges. Modeling the acquisition and operation of various devices involved decision variables and nonlinear relationships involving those decision variables that can profoundly affect the set of feasible and optimal solutions. The researchers also had to devise new techniques to ensure global optimality – upper and lower bounds on each optimal function value.

“We wanted to capture more detailed system performance characteristics and obtain more realistic solutions than existing modeling approaches,” said Leyffer. “But these same innovations required us to capture nonlinear relationships and additional variables in every time period. The result was a large, nonconvex, mixed-integer nonlinear programming problem, which is among the most challenging problems in scientific computing."

To demonstrate the capabilities of their new optimization model, the research team ran tests using a large hotel located in Los Angeles, Calif., as a case study. They then compared their solutions with those provided by existing solvers. Few of those other solvers were able to obtain solutions even for one-day instances; and those that could obtain solutions required longer run times. Moreover, the new model techniques offer the possibility of solving larger instances, up to one year – far greater than other existing solvers and essential in order to inform long-term capital investment decisions.

“Our model offers several other exciting benefits, including influencing future energy policy measures, such as the design of carbon taxes to promote the widespread adoption of alternative energy sources,” said Leyffer.

Provided by Argonne National Laboratory