OPTIMAL TECHNOLOGY SELECTION AND OPERATION OF MICROGRIDS IN COMMERCIAL BUILDINGS

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(1) Overview

The deployment of small (< 1-2 MW) clusters of generators, heat and electrical storage, efficiency investments, and combined heat and power (CHP) applications (particularly involving heat-activated cooling) in commercial buildings promises significant benefits but poses many technical and financial challenges, both in system choice and its operation; if successful, such systems may be precursors to widespread microgrid deployment, which will provide a more efficient pathway to expanding capacity and enable more customized power quality and reliability (PQR). The presented optimization approach to choosing such systems and their operating schedules uses Berkeley Lab's Distributed Energy Resources Customer Adoption Model (DER-CAM), extended to incorporate electrical storage options. DER-CAM chooses annual energy bill minimizing systems in a fully technology-neutral manner. An illustrative example for a San Francisco hotel is reported. The chosen system includes a large reciprocating engine and an absorption chiller, providing 11% cost savings and 7% carbon emission reductions under idealized circumstances.

(2) Methods

DER-CAM is a mixed-integer linear program implemented in GAMS that solves the commercial building DER investment optimization problem given a building's end-use energy loads, energy tariff structures and fuel prices, and an arbitrary list of equipment investment options. The approach is fully technology-neutral and can include energy purchases, on-site conversion, both electrical and thermal onsite harvesting, and end-use efficiency investments, such as the installation of more efficient lighting or insulation. Furthermore, system choice considers the simultaneity of the building cooling problem, i.e., results reflect the benefit of displacement of electricity demand by heat-activated cooling that lowers building peak load and, thus, the generation requirement. Regulatory (e.g., relating to emissions constraints), engineering, and investment constraints are all considered. Energy costs are calculated using a detailed utility tariff structures and fuel prices as well as amortized DER investment costs and operating and maintenance (O&M) expenditures.

The output from DER-CAM is a cost-minimizing equipment combination for the building, including CHP equipment and renewable sources along with an optimal equipment operating schedule that can serve as the basis for a microgrid control strategy. This paper reports results using recently added electrical storage capabilities, in which both electrical and thermal storage are viewed as inventories. At each hour, energy can be either added (up to the maximum capacity) or withdrawn (down to a minimum capacity to avoid damaging deep discharge). The rate at which the state of charge can change is constrained, and the state of charge decays hourly.

(3) Results

We present a numerical example using a prototypical San Francisco hotel operating in 2004. This hypothetical facility has 23 000 m^2 of floor space and a peak electrical load of 690 kW. Technology options are categorized as either *discretely* or *continuously* sized. This distinction is important to DER economics because equipment becomes more expensive in small sizes.

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Discretely sized technologies are those that would be available only in a limited number of discrete sizes, e.g., microturbines. Continuously sized technologies are available in such a large variety of sizes that it can be assumed capacity close to the optimal could be acquired, e.g., battery capacity.

Four DER-CAM runs are performed: 1. A *do nothing* case in which all DER investment is disallowed. 2. An *invest* run which finds the optimal DER investment. 3. A *low storage price* run as a sensitivity. 4. Finally, to assess the value of storage systems, a run is performed forcing the same investments as in the low storage price case but in which storage is disallowed. In the *invest* case, the optimal system consists of a large gas engine and an absorption chiller. Relative to the *do nothing* case, the expected annual savings for the optimal DER system are $51 000/a (11.2%) and the elemental carbon emissions reduction is 42 t/a (7.4%).

Figures 1 and 2 indicate example DER-CAM operating results for the thermal and electrical balances of the hotel on a typical day in January 2004 from the *low storage price* case. The area underneath the solid red line in these figures is the hourly energy demand. Area above the solid red line indicates storage charging. The various patterns in the graphs indicate the energy resources, e.g., the total electricity demand in Figure 2 may be met in one of four ways: utility purchases, on-site generation, battery storage, and absorption cooling offset (for cooling loads only).

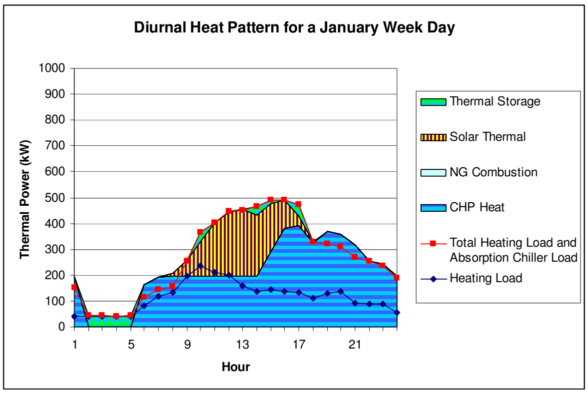

Fig. 1: Diurnal Heat Pattern for a January Week Day

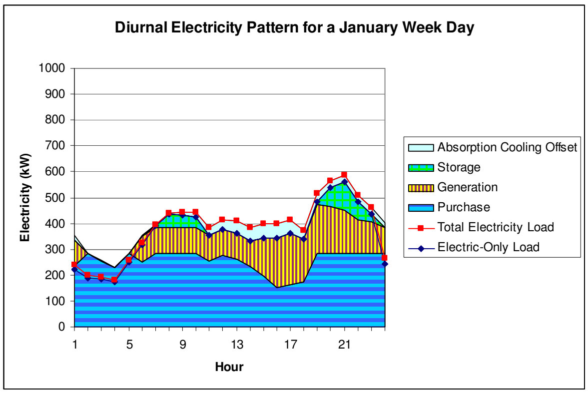

Fig. 2: Diurnal Electricity Pattern for a January Week Day

(4) Conclusions

Use of better building energy analysis and design tools can accelerate the adoption of CHP and, thereby, facilitate deployment of microgrids that can additionally deliver PQR benefits. Both thermal and electrical storage capability have been added to DER-CAM, thus making it a more useful optimization tool for on-site generation selection and operation. The new capabilities have been demonstrated by an analysis of a prototypical San Francisco hotel. Results show the wide range in complexity of optimal systems as well as the likely cost and carbon emissions reductions.

References

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