Decentralized Operation Strategies for Building Cluster

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ABSTRACT

The emerging technology in Net-Zero building and smart grids drives research moving from centralized operation decisions on a single building to decentralized decisions on a group of buildings, termed a building cluster which shares energy resources locally and globally. However, current research has focused on developing an accurate simulation of single building energy usage which limits its application to building clusters as scenarios such as energy sharing and competition cannot be modeled and studied. We hypothesize that the study of energy usage for a group of buildings instead of one single building will result in a cost effective building system which in turn will be resilient to power disruption. To this end, this research develops a decision model based on a building cluster simulator with each building modeled by energy consumption, storage and generation sub modules. Assuming each building is interested in minimizing its energy cost, a bi-level operation decision framework based on a Particle Swarm Optimization (PSO) is proposed to study the tradeoff in energy usage among the group of buildings. Two additional metrics, measuring the comfort level and the degree of dependencies on the power grid are introduced for the analysis. The experimental result demonstrates that the proposed framework is capable of deriving the Pareto solutions for the building cluster in a decentralized manner. The Pareto solutions not only enable multiple dimensional tradeoff analysis, but also provide valuable insight for determining pricing mechanisms and power grid capacity.

INTRODUCTION

According to the Electric Power Research Institute (EPRI), the electricity consumption of the U.S. grew 1.7% annually from 1996 to 2006 with the expectation of total growth through 2030 being 26% [1]. Buildings (approximately half commercial and half residential) consume over 70% of the electricity among all the consumption units [2]. The fact is between 4 and 20% of energy used for Heating, Ventilating and Air Conditioning (HVAC), lighting and refrigeration in buildings is wasted due to problems with system operation. Therefore, extensive research in the past two decades has explored optimal operation strategies including on-site generation and storage for Net-Zero buildings to reduce energy cost and improve energy efficiency for building clusters.

While promising, we notice that most literature focuses on operation strategies for one subsystem only, that is, HVAC, energy storage or energy generation. Considering a building is an integrated system as a whole, studying the interactions among the subsystems is necessary. Secondly, even though there exists research exploring a building as a system consisting of subsystems, a majority of the research formulates the decision problem for a single building only. Realizing the emerging technologies in multi-energy source building, Net-Zero energy building [3] and Smart Grid [4], developing a decentralized decision framework modeling the coordination among a cluster of buildings to obtain Pareto decisions which enable tradeoff analysis is becoming urgently critical.

METHODS

Integrated Building Energy System Simulator

Decentralized Decision Model

Decision Variables

PSO Demonstration

Decentralized Decision Framework

RESULTS

Pareto Analysis

- Two buildings located in Phoenix are studied
- Two buildings (Mass building building and Light building) are simulated. The buildings (building 1 and building 2) have 39% of the load in the lighting and air conditioning systems. The buildings (building 1 and building 2) have 39% of the load in the lighting and air conditioning systems.

- Energy usage for each building is modeled by energy consumption, storage and generation sub modules. Assuming each building is interested in minimizing its energy cost, a bi-level operation decision framework based on a Particle Swarm Optimization (PSO) is proposed to study the tradeoff in energy usage among the group of buildings. Two additional metrics, measuring the comfort level and the degree of dependencies on the power grid are introduced for the analysis. The experimental result demonstrates that the proposed framework is capable of deriving the Pareto solutions for the building cluster in a decentralized manner. The Pareto solutions not only enable multiple dimensional tradeoff analysis, but also provide valuable insight for determining pricing mechanisms and power grid capacity.

CONCLUSIONS

Conclusions: The proposed decentralized decision framework is capable for deriving Pareto operation decisions which can assist building managers:

- make decisions on different metrics
- choose pricing mechanisms effectively
- increase Net-Zero buildings’ disaster resilience capability

Future Works:

- improve the performance of the decision framework in terms of solution quality and computational cost
- refine time scale to make it capable for hourly real-time decisions
- consider uncertainty and dynamics existing in the decision model to gassimulate building clusters be adapted to the dynamic environment in real time

REFERENCES


ACCOMPLISHMENTS

The revision for paper “Decentralized Operation Strategies for an Integrated Building Energy System using a Memetic Algorithm” has been re-submitted to European Journal of Operational Research on April, 2011.