Ogimoto Laboratory

Ogimoto Laboratory

Collaborative Research Center for Energy Engineering Institute of Industrial Science, the University of Tokyo

Applying Optimization Techniques to Decentralized Energy Management Systems for Balancing Power Supply and Demand

The use of renewable energy sources, especially photovoltaic (PV) and wind power generation, is now expanding on a global scale. Japan has set high goals for the introduction of thesetechnologies, which have attracted more and more attention following the Great East Japan Earthquake and the Fukushima nuclear accident in March 2011. However, PV and wind power generation are characterized by seasonal and hourly variations as well as irregular variations caused by changes in the weather. Therefore, in addition to balancing supply and demand, to ensure a sufficient and stable power supply we have to also solve various technical problems such as voltage increases and frequency changes.

To achieve a supply-demand balance in future power systems, it is imperative that we should not only apply pumped-storage power generation or large-scale batteries on the supply side but also focus on residential power usage, storage, and generation on the demand side.

The Ogimoto Laboratory is a leader in studies about using the Home Energy Management System (HEMS) to better manage energy through the use of optimization techniques across both supply and demand, including controlling equipment on the demand side to contribute energy to the overall electric power system. Figure 1. shows the system for balancing supply and demand where centralized and decentralized energy management work together to address the needs of both the overall power system, as well as the needs of a single building or community.

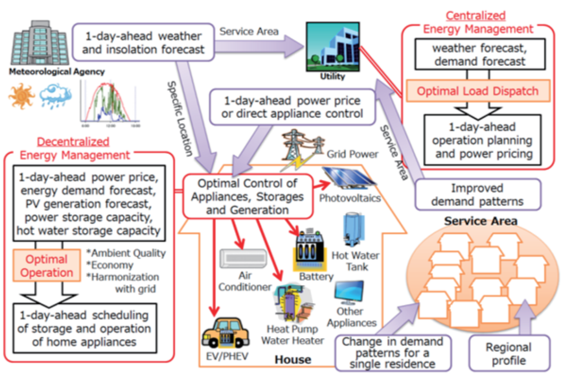


Fig. 1 Centralized / decentralized energy management coordination

Under a centralized energy management system, power companies forecast the amount of PV generation and electricity demand in the service area and calculate the optimal load dispatch across the power plants. In situations where there is insufficient capability to balance supply and demand through equipment controlled by the power company, a signal for managing residential power usage could be sent directly to customers prior to the fact. For example, if an increase in demand is desired, a method could be used in which the price for electrical power would be lowered and customers notified a day in advance, or a higher price for power set when a decrease in demand is desired. On the other hand, the decentralized energy management calculates the most economical operation schedules of domestic electric appliances, within a range that will not interfere with the comfort of living or working environments, by using forecasted energy demand and PV generation and also using next-day electricity prices sent from the utility. By coordinating localized optimization, attained by implementing decentalized energy management for residences and office buildings, with overall regional optimization, based on centralized energy management performed by power companies, we aim for a system that can fully benefit both consumers and power companies.

The Ogimoto Laboratory is engaged in development of a scheduling model for optimized household appliance operation (see Fig. 2), which would utilize the functions of the Gurobi Optimizer mixed integer linear programming method (MILP) to quantitatively evaluate effects of the optimal control of household appliance, using forecasted levels of next-day energy service and PV generation demand, as well as information on demand adjustment incentives from power companies.

As a result of the application of actual residential data, it was discovered that setting lower daytime power rates for clear weather days in May, when the supply-demand adjustment is most difficult in Japan, can create more daytime power demand for residential heat pump water heaters or storage batteries, thus consuming surplus PV power and suppressing reverse flow (see Fig. 3). In addition, it was confirmed that residential power demand can be used to adjust the supply-demand balance, through a suitable setting of power prices in response to weather conditions.

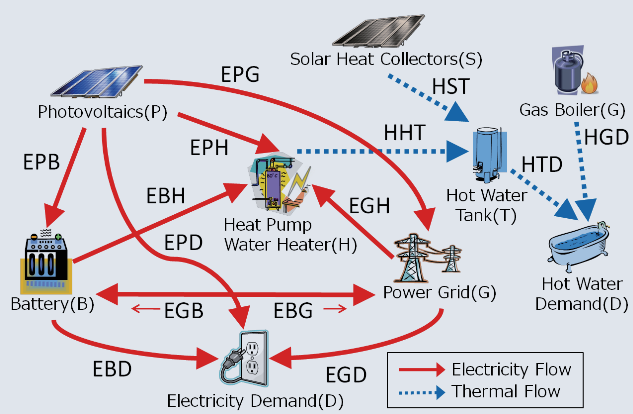


Fig. 2 Targeted appliances and energy flow

Ogimoto Laboratory

Collaborative Research Center for Energy Engineering Institute of Industrial Science, the University of Tokyo

Using the Gurobi Optimizer

While my research up until this point has utilized other mathematical programming solvers, I began using the Gurobi Optimizer in 2010 after a fellow researcher introduced me to it. Since my research is in the energy field and not in optimization research, an important issue for me was determining how quickly Gurobi could be introduced into the research. Despite the decentralized energy management model requiring high-speed solutions to complex mixed-integer linear programming (MILP) problems, the Gurobi Optimizer does not require any particularly difficult settings at the time of installation, and I was able to become familiarized with its use in a short time.

With the help of the Gurobi Optimizer, I am now able to solve the MILP problems in much less time, greatly improving research efficiency. While the Gurobi Optimizer is capable of solving MILP problems at high speed, with their focus on continued improvements, we are looking forward to even faster speeds and a more compact size in future. The ability to immediately solve large-scale MILP problems at speeds that make it practical for regular use, marks the first step toward marketability of decentralized energy management systems. I am convinced that with the speed of the Gurobi Optimizer, it will be of great assistance as an optimization technology for solving energy problems.

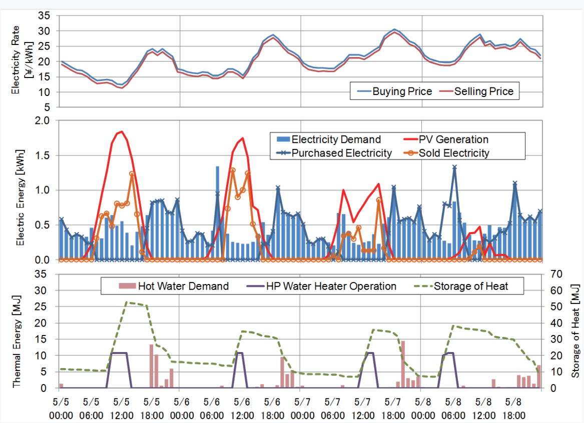


Fig. 3 Optimizing operation of heat pump water heater by using variable power rates

Gurobi Optimizer Exclusive Distributor in Japan

October Sky Co., Ltd.

Kotobukicho KY Building
1-8-1 Kotobukicho Fuchu-shi Tokyo 183-0056
Tel 042-207-3020 (Main) Fax 042-207-3022
URL : http://www.octobersky.jp
e-mail : info@octobersky.jp

Gurobi Optimizer Sales Outside of Japan

Gurobi Optimization, LLC.

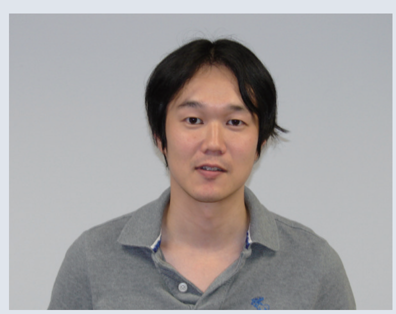
9450 SW Gemini Dr #90729
Beaverton, Oregon, 97008-7105 USA
Tel +1 713-871-9341 (Main) Fax +1 713-960-0793
URL : http://www.gurobi.com
e-mail : info@gurobi.com

An overview - The University of Tokyo, Collaborative Research Center for Energy Engineering, Ogimoto Laboratory

The Collaborative Research Center for Energy Engineering is a research center on the University of Tokyo campus established jointly by the Institute of Industrial Science and the School of Engineering on January 1, 2008, as an interdisciplinary educational and research network dedicated to energy. It was established for the purpose of researching current energy-related issues, with an eye towards consolidating the training of those who will shoulder the responsibility of providing energy for the next generation, as well as playing a role as a think tank for resolution of these issues, and assisting in the formation of an international core for education and research in energy-related fields. The Center consists of three research departments, in energy materials, energy systems, and energy processes.

Within the Center, the Ogimoto Laboratory is engaged in research into energy strategy, long-term materials and energy supply and demand analysis and evaluation, dynamic energy supply and demand analysis and evaluation, energy management and renewable energy. In particular, research in the energy management and renewable energy fields is aimed towards effective use of renewable energy technologies that could conceivably be introduced in future.

Because the output from renewable energy sources tends to vary, a number of issues have emerged related to its wide-scale introduction. Research is progressing on the optimal configuration and control of energy technologies, and on the coordinated control and operation of centralized/decentralized energy management systems, with the aim of stimulating demand for the wide introduction of power produced by renewable energy sources.



Assistant Professor
Ogimoto Laboratory, Institure of Industrial Science
The University of Tokyo

Takashi Ikegami, Ph.D.