Novel Controls for Economic Dispatch of Combined Cooling, Heating and Power (CHP) Systems

Enabling More Widespread Use of CHP in Light Industrial, Commercial, and Institutional Applications

This project developed and demonstrated novel algorithms and dynamic control technology for optimal economic use of CHP systems under 15 MW. Combined cooling, heating and power (CHP) technologies have successfully entered the market for larger (over 20 MW) applications. Smaller systems, between 500 kW and 15 MW, have not seen similar market penetration.

Introduction

Among the barriers to more widespread use of CHP technologies is the dynamic nature and relative non-coincidence of the thermal and electrical loads in many of the smaller applications.

The goal of this project was to develop and demonstrate algorithms and control systems that enable optimal economic use of CHP systems in light industrial, commercial, and institutional applications.

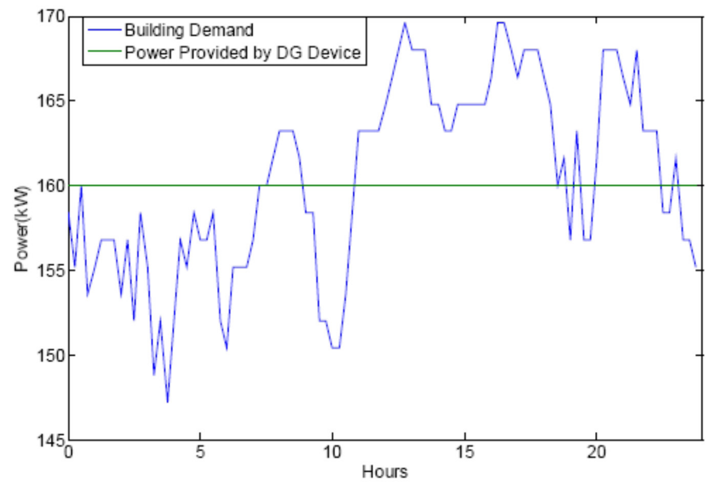
Benefits for Our Industry and Our Nation

The CHP control systems and algorithms developed are available for use to increase market penetration of CHP systems in light industrial, commercial, and institutional applications. CHP systems are much more efficient than separate generation of thermal power and electricity, so that greater use of these systems results in significant energy savings and greenhouse gas and pollutant emission reductions.

The control algorithms can improve the economic performance characteristics of CHP systems by maximizing the value of the electricity and thermal power produced. This results in financial savings for system owners, while emissions are reduced and energy resources are conserved.

Applications in Our Nation's Industry

The control technology encourages more widespread use of CHP systems in light industrial, commercial, and institutional sectors. The light industrial market for CHP is estimated to be 18–54 GW. Market potential for similar applications in the commercial and institutional sectors is estimated at 75 GW.



The dynamic nature and non-coincidence of building energy demands with power generated by distributed energy resources creates a challenge for system control and integration.
Illustration courtesy of University of California, Irvine.

Project Description

Novel control algorithms and systems were developed and demonstrated to optimize economic use of CHP systems in light industrial, commercial, and institutional applications.

To achieve this, existing CHP systems and typical electrical, heating, and cooling loads were measured and modeled. Dynamic models were developed for gas turbine, steam turbine, heat recovery steam generator, chiller, thermal energy storage, fuel cells, batteries and other distributed energy devices and systems. These dynamic models were verified by comparison to measurements.

Using the verified dynamic models and data acquired, algorithms and architecture for economic dispatch of heating, cooling, and electrical power were developed and applied to Siemens control technology. The new control technology was then demonstrated in the existing CHP system of UC Irvine.

Barriers

The project has developed a means of overcoming some of the following barriers to CHP adoption:

- Challenges created by the highly dynamic nature and non-coincidence of thermal and electrical loads in the targeted applications
- Lack of accurate and realistic dynamic modeling of thermal and electrical loads and CHP systems

- Difficulty in integrating developed algorithms into control technology software and hardware

Pathways

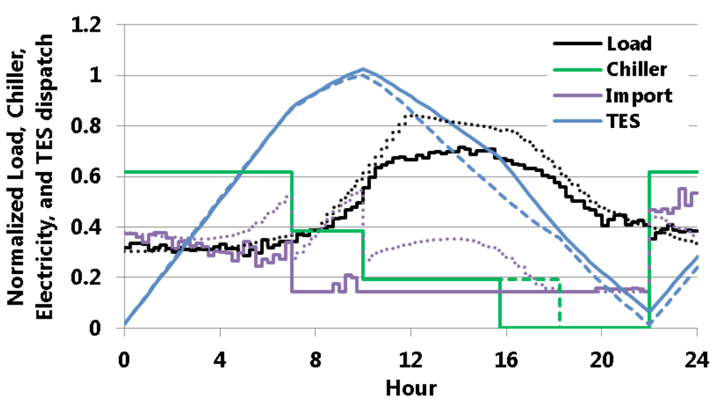
Based upon the CHP models and load measurements, algorithms and architecture for economic dispatch of cooling, heating, and power from CHP systems were developed and demonstrated at the UC Irvine central plant. Application of the novel controls to the UC Irvine central plant produced economic savings up to 5% in winter and almost 9% in summer.

January	Total Electric Charges	% Saved	Fuel	Total	% Saved
Actual Cost	$ 238,210		$ 489,250	$ 727,460	
Optimal Dispatch	$ 202,930	14.82%	$ 487,740	$ 690,670	5.06%
Predictive Dispatch	$ 207,640	12.84%	$ 486,120	$ 693,760	4.64%

July	Total Electric Charges	% Saved	Fuel	Total	% Saved
Actual Cost	$ 315,990		$ 482,910	$ 798,900	
Optimal Dispatch	$ 236,430	25.18%	$ 491,470	$ 727,900	8.89%
Predictive Dispatch	$ 237,950	24.70%	$ 491,220	$ 729,170	8.73%

Application of novel controls to the UC Irvine central plant resulted in savings for both winter and summer months. *Results courtesy of University of California, Irvine.*

Savings were achieved by use of model-predictive control strategies for the dispatch of the gas turbine, steam turbine, chillers and thermal energy storage (TES) systems.



Example diurnal dispatch of chiller plant and thermal energy storage system using model-predictive control. *Results courtesy of University of California, Irvine.*

Milestones

The project started in early 2010 and was completed in December of 2013. Project deliverables included:

- Dynamic physical models of combined cooling, heating and power technologies verified by comparison to data
- Dynamic data from Light Industrial, Commercial, and Institutional electrical and thermal loads
- Novel dynamic control algorithms
- Demonstration and verification of the control algorithms into control technology software and hardware

Commercialization

The new control concepts have been integrated into the Siemens line of industry automation and building monitoring and control products.

Project Partners

University of California, Irvine (UCI)
Irvine, California
Principal Investigators: Jack Brouwer, jb@apep.uci.edu;
Scott Samuelsen, gss@uci.edu

Siemens Corporate Research
Princeton, New Jersey

California Energy Commission
Sacramento, California

For additional information, please contact

Bob Gemmer
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5885
Email: Bob.Gemmer@ee.doe.gov

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