New Approaches in Automating and Optimizing Demand Response to Solve Peak Load Management Problems

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Keywords: Automating, Optimizing, Demand Response

Abstract

Grid power demand peaks and increasing supply/demand in-balances create management challenges for utilities. These challenges are increasingly being resolved using non-"supply side" solutions. While the use of curtailable load in Demand Response (DR) applications is a powerful solution in managing the problem of grid load peaks, it is not without its challenges. Delivering DR from commercial, industrial and institutional (C/I/I) buildings can be difficult, costly and risky for building owners. DR participation from these electricity customers can be unreliable and unpredictable unless the right tools, processes, economic incentives, systems and training are in place.

Use of the thermal mass of a building in the C/I/I markets can be used as a reliable and predictable source of system DR capacity. This paper will discuss how automated and optimized DR technology can build and implement accurate relationships between DR lead time, incentives, DR duration, external environmental conditions and building occupancy by understanding the HVAC capacity and thermal characteristics of a building. New technologies provide utilities better insight into available customer DR resources. These new technologies automatically inform utilities the future load profiles of buildings enrolled in DR programs – allowing utilities to better plan grid operations before a critical peak event occurs.

Market Needs & Motivations

Emission regulations, RPS, reliability, supply, transmission constraints and infrastructure concerns are driving the large-scale deployment of necessary capabilities such as the smart grid, dynamic pricing, and demand-response programs.

The need for more price-responsive (elastic) demand and pricing is forcing the deployment of advanced energy management systems in residential and commercial-sized buildings.

Optimizing the operation of Heating Ventilation and Cooling (HVAC) systems is critical since HVAC systems account for 30-40% of the total energy demand in buildings [1] in the U.S.

1. THE CASE FOR PREDICTIVE OPTIMIZATION ENERGY SOFTWARE FOR BUILDINGS

Current State:

Existing Building Management Systems (BMS) serve as interfaces for building operator by monitoring sensor data and modify operational (set-point) conditions of air-handling units, thermostats, chillers, and boilers as occupancy, external weather and price conditions change throughout the day. BMS systems are equipped with basic controllers that track the set-points and (may) include basic optimization functions to minimize energy consumption and cost by using pre-cooling and economizers. The BMS' human operator typically makes most of the economic and operational decisions in the building. This process is usually reactive in nature and is based on historical aspects. The existing methods can be inefficient. Weather and energy market conditions are highly dynamic. BMS operators have access to very limited real-time information about pending weather, building energy loads & market prices.

This lack of **systematic knowledge** and the inability of BMS mechanisms to accurately quantify and anticipate the effect of weather, occupancy, building design, and market prices on the building's dynamic response expose a building to highly volatile real-time prices & increased costs. It limits the building's participation in electricity markets.

Limited building knowledge & the lack of predictive abilities in the building increase the serving utility's supply requirements. As a result, utilities see sporadic and inconsistent participation in demand response when and where they need it. Utilities typically have inaccurate data as to what demand reductions a given building can deliver.

New Approaches:

Predictive modeling and system control software developed by The Australian Government's Research Organization (CSIRO) and commercialized by BuildingIQ has been shown to produce **15-40% ongoing HVAC energy savings** and up to **30% peak load reduction** during DR events. BuildingIQ installations include office buildings, retail malls, utility programs and U.S. Dept. of Energy Facilities.

Predictive building management systems make use of weather forecasts, energy price signals and predictive dynamic models of the building to anticipate trends to minimize the building's HVAC requirements. The key principle is that the building has sufficient momentum or thermal mass to offset the conditioned space requirements over extended periods of time without affecting comfort conditions. This "coordination" principle is key to both saving energy and to shifting cooling demands throughout the day [2].

1.1. Key Attributes of the solution:

- Software that learns a building's thermal dynamics, occupancy patterns and, when coupled with internal/external data, (such as real-time and "ahead" energy pricing, utility incentives, and real-time/forecasted weather) optimizes the building's building management system (BMS) settings to reduce energy and/or cost while maintaining comfort.
- Plugs into virtually any BMS in new or existing buildings to leverage existing infrastructure and reduced installation/operating costs (via BacNet, OPC, Tridium JACE, etc.)
- Interfaces with Utility Automated Demand Response programs via OpenAdr protocols
- The Solution is Software only; no system upgrades or new sensors are (generally) required.
- Building and Multi-Building (portfolio-level) capabilities for either aggregation of DR or allocation of DR commitments.
- The solution is sold on a subscription basis, requiring no end-user or utility up-front capital.

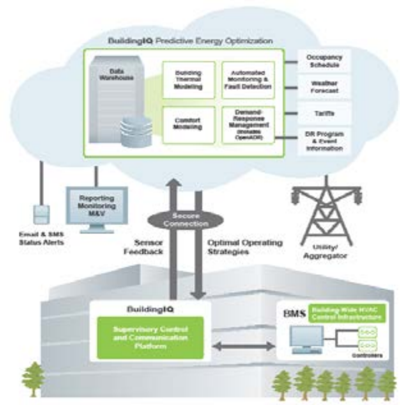


Figure 1.
System Overview

The system performs **Predictive, adaptive, continuous optimization** of building energy consumption.

- Key inputs:
  - Existing building data
  - Historical, Real-time& Forecasted External data (utility pricing, weather)
  - Tenant/Occupant feedback (zone temps, etc.)
- Creates unique model (32 key attributes) of building dynamics; refined continuosly
- Model enables planned building operating profile; algorithms optimize performance
- Optimized forecast drives BMS inputs; continuously updated
- Tenant/Occupant comfort is the key input in optimization strategies & implementation (using ASHRAE 90.1 and 55 comfort model)

The system modeling initially learns the building's characteristics and operating parameters.

- Unlike EnergyPlus, the model is not structural.
- Uses dynamic systems theory and time series analysis

After the system modeling learns the building's characteristics and operating parameters it then goes into an active operational mode with constant updates and system adjustments during the various seasons.

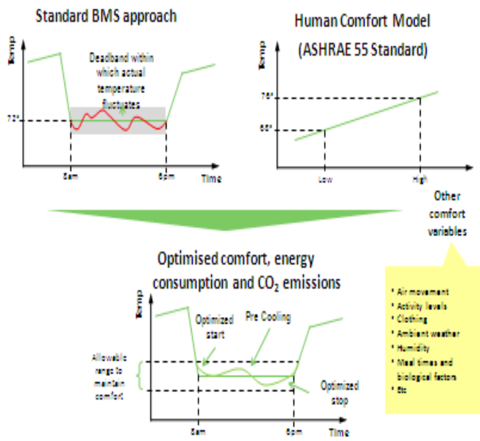


Figure 2.
The Comfort Model

The system can utilize **"comfort"** as a governing factor if this attribute is more important to the building owners or operators than energy cost or energy consumption.

The system operates and fine-tunes itself within the existing control system deadbands, throttling ranges. It may do setpoint adjustments within permissible parameters.

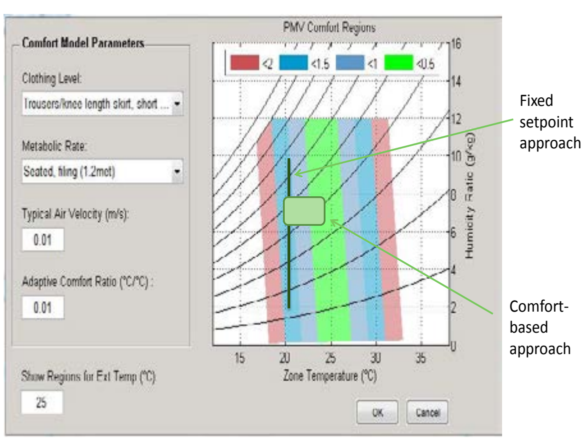
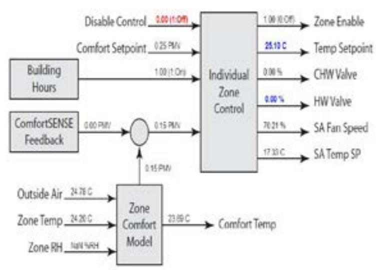


Figure 3.
Adaptive Control

What does the System Read & Control?



BuildingIQ Interaction:

- Read/Write (Optimized Start/ Stop)
- Write (in Zone Control Mode)
- Read (+lock out)
- Read (+lock out)
- Read (+minimum air control)
- Read (+write in SA Control Mode)
- Read (Outside Air)
- Read (Zone Temperature)

Figure 4.
Control Attributes

Not all BMS points are "mapped" into the predicative modeling and control system, only key system points. Ideally, the building will have Direct Digital Control (DDC) BMS sub-components to the AHU level, the building utility meter data as inputs into the BMS and some indication of chiller loading (such as chiller amps or kw or btu) .

The system incorporates interactions with key BMS elements to "trim" and/or fine tune HVAC operations. Operating strategies for satisfying occupant space needs can include such initiatives as use of increased Air Handler static pressure in lieu of Chiller generated BTUs.

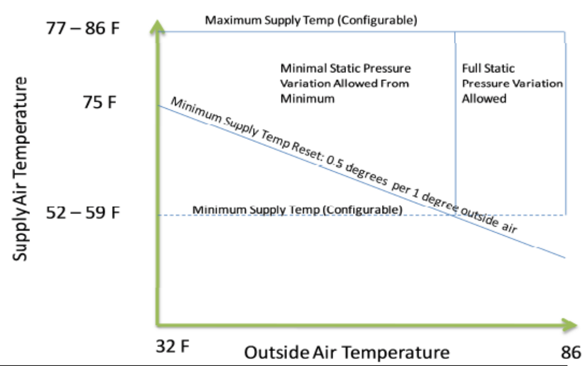


Figure 5.
Static Pressure vs. Chiller BTU adjustment

1.2. Automated Demand Response:

Additional savings and results may be achieved by implementing automated demand response control optimization Building management strategies.

Predictive Energy Optimization allows Building Managers and Owners some unique strategies and tactics with respect to Demand Response program participation, such as:

- A better understand the building's capacity to shed load
- A better understand the energy, cost and comfort impact of a DR event before the event
- Optimize the building operations around the DR event.
- Incorporates electronic signal from the utility to the BuildingIQ system and the BMS: DR event(s) are automatically incorporated into optimization parameters
- Planning the building's response for DR events that are tailored to the building's unique design, the building's Tenant comfort parameters, weather and the specific DR program structure/elements
- Having the building adapt in real-time to changes in internal and external conditions
- Real-time tracking of impact and results

Incorporation of Optimized Automated DR can:

- Improve the DR program participation value proposition for building owners
  - Automate communications, management and reporting of Demand Response events (OpenADR, AutoDR and web-based signals)
  - Optimize building for DR event while minimizing tenant/occupant comfort impact
  - Minimize Peak Day Pricing penalties
  - Manage buildings on an individual or aggregate basis to share load
- Give an insight to utilities into the Peak Demand & available resources at the "Edge of the SmartGrid" by providing:
  - A detailed understanding of the building's consumption history, trends and dynamics
  - The ability to forecast demand at the building level (day ahead or 4 hours ahead, etc.), as well as run demand scenarios based on weather, pricing and comfort requirements
  - The ability to forecast demand at an aggregated portfolio, distribution circuit or specific geography level

1.3. Typical Results:

15-40% HVAC Energy & 10-30% Demand Savings

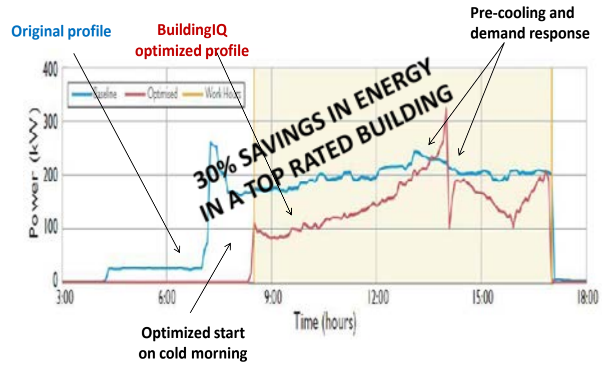


Figure 6.
High Peak-Tariff/ Low Demand Charge Example

Additionally, Buildings implementing predictive modeling and control strategies have seen these sorts of returns and improvements:

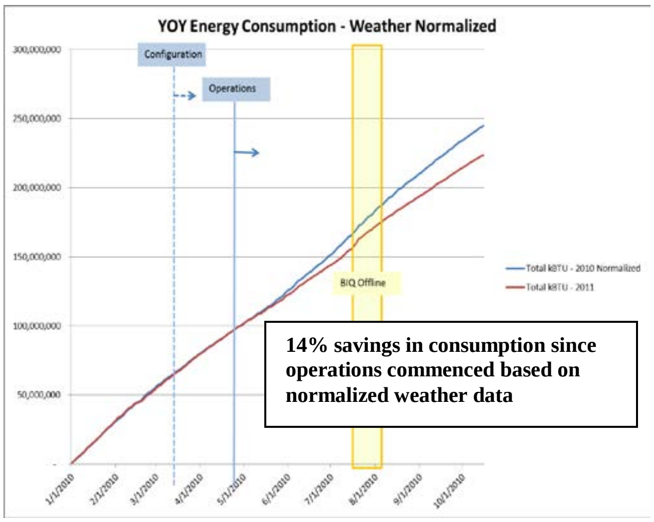
ENERGY STAR® Rating		Gross Annual Savings		Property Value Impact @ 8% cap rate		Pay-Back mos.
Before	After	200k ft² $36k Cost	500k ft² $90k Cost	200k ft²	500k ft²	
95	96	$ 60,765	$151,914	$ 815,946	$ 2,039,866	7
90	93	$ 72,325	$180,812	$ 1,056,767	$ 2,641,916	6
85	89	$ 81,377	$203,444	$ 1,245,364	$ 3,113,411	5
80	85	$ 89,269	$223,174	$ 1,409,780	$ 3,524,450	5
75	80	$ 96,530	$241,324	$ 1,561,031	$ 3,902,579	4

Table 1.
Sample Savings results

Increases of 5-10 Energy Star Points are typical as are less than 1 year equivalent paybacks in many regions of North America, Europe and Australia.

Retention of tenants, property values and capital equipment life extensions are additional benefits resulting from deployment of predictive modeling and control systems.

The chart below depicts actual savings from an installed Predictive Modeling and Control system in New York City. This system is working with an existing DDC based BMS in a Class “A” multi-tenant office complex in a fully de-regulated market, with volatile energy price exposure risk.



<u>Savings to date on 2.5M sq. ft. in NYC</u>

$359k energy expense reduction to date (6 mos.)
$5 in savings for every $1 spent on subscription fee

Figure 7.
Specific Savings Example

1.4. Summary

Use of predictive modeling/control tools in conjunction with existing Building Management Systems can be a very effective tool for C/I/I Building Owner/Operators, occupants and utilities in minimizing operational costs, avoiding capital expenditures and improving comfort. Again:

- **Strong stand-alone ROI (with or without utility incentives/rebates or tax credits)**
- **Improved value proposition for building owners to participate in DR programs**
- **Unique insight for utilities into the Peak Demand and available customer resources at the “Edge of the SmartGrid”**
- **New revenue sources for property owners/managers**
- **Retention of tenants and property values**
- **Open, BMS vendor & HVAC manufacturer “neutral” solutions**

1.5. Reference Citations

[1] U.S. Department of Energy’s Energy Information Administration (“EIA”) www.eia.doe.gov

[2] J. K. Ward, J. Wall, S. West, and R. de Dear. Beyond comfort managing the impact of HVAC control on the outside world. In Proceedings of Conference: Air Conditioning and the Low Carbon Cooling Challenge, 2008.

1.6 Biography of author

David Olson is V.P. of Utility Programs for BuildingIQ. He previously held executive positions in Sales, Business Development and General Management for Tersus Energy Plc, The Electrical Power Research Institute (“EPRI”), Honeywell and Constellation/New Energy.

Mr. Olson received a BS in Architectural Engineering and a BS in Business Administration, both from the University of Colorado at Boulder. He has had post-graduate MBA coursework at the Univ. of San Diego and at the Stanford University Graduate Business School. Mr. Olson is a registered Professional Engineer. He is active in numerous industry trade associations. He is currently a board member of three privately held companies.

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