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Optimized Building Controls and Grid Integration

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ABSTRACT

Commercial building controls can have a dramatic impact in achieving energy efficiency. Properly designed and implemented integrated controls provide a tool that helps deliver efficiency and supports operation of the building. These same systems can be used to provide building to grid integration, allowing the building to provide grid services along with support for fault detection and analytics.

As an industry though, we often fail to deliver control systems that meet these goals. This paper covers the design of integrated controls, key efficiency strategies, and programs under way to improve the control design and delivery process. Case studies on both improved efficiency as well as building to grid integration is included.

Keywords—Building controls, efficiency, integration, building to grid, open protocols, optimization

INTRODUCTION

Commercial buildings rely on control systems for safe and efficient operation. Initially, controls were developed primarily for controlling temperature. In fact, the earliest controllers were called “regulators” since they would regulate the temperature, typically with some form of a mechanical control. In the US and Europe, these systems evolved over the years from being primarily mechanical to using sophisticated electronic or pneumatic logic for both control and actuation. As computer technology emerged from 1970 – 1980, building controls evolved into the use of direct digital control (DDC). This allowed for control systems that were not only more accurate and repeatable, but with the added benefit of being able to utilize communications for easy monitoring of system operation remotely. By the 1990s, the use of building automation systems (BAS) became cost effective and common for new buildings. However, these new systems were frustrating for owners since they were highly proprietary, and it was often difficult and expensive to get service and support for an existing system and even more expensive to expand it. This spurred the industry wide development of open communications protocols including BACnet (BACnet International, 2019) from ASHRAE, Lon Works (LonMark International, 2019), and Modbus (Modbus International, 2019). Today, the majority of new systems utilize open protocols, while existing buildings are a mix of open and proprietary systems.

Note that the author works as a consulting engineer and researcher in the field of commercial controls and is based in North America. As a result, most of his project experience is on buildings in North America, however he has been involved in projects in India as well as Europe and Asia. The control products being used in North America are from large global suppliers including Honeywell International, Schneider Electric, Johnson Controls and United Technologies. These are the same suppliers that are also involved in markets including India, Europe and Asia. There are however a few key differences between what may be found in North America and in other markets. One is that the vast majority of large commercial buildings in North America were constructed prior to the year 2000 and as a result, often have either obsolete control systems or are on their second or third generation of controls. Evolving markets often have the benefit of newer buildings that may have been designed and constructed using more recent technology. There is also a difference in system types found in the US. US HVAC systems are largely air based, while systems found in other markets may tend to be more refrigerant (i.e. VRF, mini splits) based or water based (fan coils). The basics of controls optimization and grid integration as described in this paper, however, readily apply to systems found in all markets globally. Unfortunately, the challenges found with the inability to get systems to operate at their full efficiency also exist globally.

Building controls can be an effective tool to operate buildings for optimum efficiency. They do this through the use of sensors, actuators and control logic that is used to condition spaces only when required, and to deliver the required level of heating or cooling to maintain occupant comfort and safety. A properly "optimized" control system can operate a building at peak efficiency. However, a system that is poorly designed, not correctly installed, or improperly operated can result in significant energy waste. Studies and energy audits regularly show buildings using from 10% to 50% more energy than needed often due to poor control system performance. (N. Fernandez, 2017). Figure 1 illustrates the challenge found in many buildings. The control system is designed for an initial level of efficiency, which due to various reasons is operating at a lower level of efficiency (as measured by the energy use index or EUI). The system can be recommissioned to bring it back to the original design; however, they tend to drift back to run at reduced efficiency. Proper optimized control design coupled with tools improve performance provides the ability to improve performance over time.

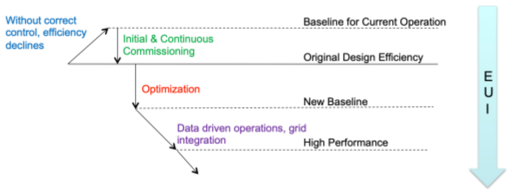

Figure 1: Building Efficiency over Time

Building control systems are also able to receive signals based on the needs of the electrical grid. The control system can then take a pre-defined control action. For example, on a hot day there may be more demand for electricity than is available. The grid operator can respond to this by dispatching additional generating or storage capacity (if available), or by restricting usage through rolling blackouts. An alternative is to send a signal to buildings that in turn has them minimize usage for a period of time. This is often called "Shedding" or "Demand Response" control. Additional grid services that can be provided by buildings include the ability to "shift" their demand, as well as to "modulate" (or shimmy) loads. See figure 2 and (Piette, 2017). Shifting demand is an effective strategy for management of a grid that has a high percentage of intermittent renewable generating resources. In a shifting strategy the building shifts its energy use to accommodate the grid. For example, at noon on a sunny day the electrical grid may have excess capacity from Photo Voltaic (PV) generation. A signal is sent to the building requesting a shift. The building control system would then be able to trigger additional loads that could charge a thermal storage plant, pre-cool the building, or charge an on-site battery. Modulating or shimmy is the least mature building to grid strategy. In this strategy the grid is requesting fast changes so that the voltage and frequency is maintained. Most building control systems are not designed for fast action, and as a result most modulating strategies rely on other systems such as adjustments to solar PV inverters. The use of building to grid control is an important strategy for managing an electrical grid that has a high percentage of intermittent renewable resources, allowing for buildings to flex their usage to balance the available supply. Note that most building to grid control for commercial buildings today is limited to demand response (shed) and is often a fairly manual process initiated by a building operator at the request of the utility. The use of more automated and sophisticated building to grid strategies is largely a research topic and is not yet being broadly deployed.

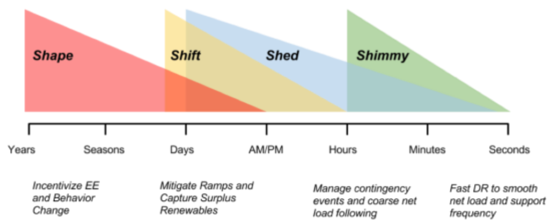

Figure 2: Building to Grid Services (courtesy of DRCC)

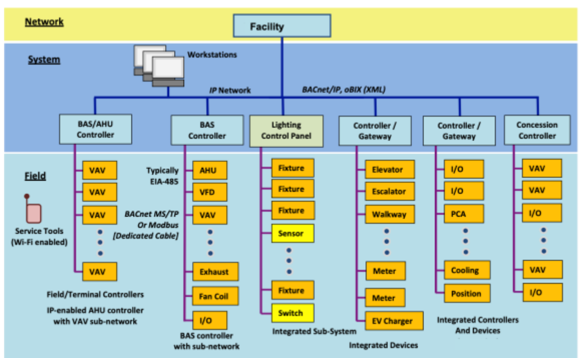

Figure 3: Integrated Commercial Building Control Architecture

HVAC Control

In most buildings, Heating Ventilating and Air Conditioning (HVAC) is the largest consumer of energy in the building. There are many ways to reduce HVAC energy use including the use of more efficient building envelope design and construction, improved equipment efficiency, and proper operations and maintenance. The use of controls also has a large impact on energy used for HVAC. The key elements to an optimized HVAC control design include:

- Only run when needed: Equipment that is turned off is generally at its most efficient point of operation! Systems should be operated as required to maintain occupant comfort and safety. However, there is no reason to run a system for an area that is not occupied. The use of schedules, occupancy sensing, and algorithms such as optimal start allow for control systems to only operate when required.
- Optimization: The basics of optimization are based on the following:
    - Free Cooling: Use cool and dry outdoor air when possible in place of mechanically cooling.
    - No Simultaneous Heat / Cool: Avoid cooling down air then heating it again as is done, for example, in a reheat system.
    - Select Maximum Efficiency: Operate the most efficient combination of equipment to meet the load of the building. For example, if there are multiple chillers, the most efficient combination of machines would be selected to run to meet the load.
    - Deliver at Minimum Energy: Provide comfort by moving the least possible amount of air and water, at the lowest possible pressure. By reducing both flow (kinetic energy) and pressure (potential energy), comfort can be provided with minimal energy. An example of this is resetting the static pressure in a pumping system based on the valve positions so that the most extreme valve is always 100% open.
    - Manage Ventilation: Deliver the required level of fresh air to each zone based on actual occupancy, not the design assumptions.

Lighting Control

Since lighting is typically the number two energy user in a commercial building, providing better control is a good strategy to reducing energy use. There are several control strategies typically used for lighting control. These include:

- Scheduling: Lights that serve common areas such as lobbies, corridors, and open office areas can be scheduled so that they are shut off when the areas are not in use. Exterior lights can also be scheduled or may be controlled based on daylight levels (with a photocell).
- Occupancy Based Control: For areas with intermittent occupancy such as classrooms, conference rooms, and private offices, the best option is to have lighting controlled based on occupancy sensing. There are two strategies that are often used. One is to use a motion sensor to turn the lights on when activity is sensed. The other strategy is called vacancy control, and it requires that the lights be turned on manually using a switch, and that the motion sensor will turn the lights off when no activity has been sensed for a time interval.
- Daylight Harvesting: In many zones, there may be windows and skylights that provide daylight. In these zones lighting sensors can be used to measure the daylight level, and lights can then be dimmed or turned off to hold a constant level of lighting in the zone.

Lighting control systems have evolved from being simple relay-based switching of large banks of lights to being deployed directly as part of the fixture. The latest lighting control solutions embed a small sensor in each fixture that is able to sense daylight levels and occupancy. They can communicate wirelessly so that the fixtures can share both data and control. For example, a group of fixtures in a conference room might be programmed to turn on and off together, and to adjust their output based on the level of light coming through the windows. They also can be connected to local control (which replaces the traditional light switch) and be integrated into a building control system.

Since lighting control and HVAC both require information about occupancy, the sensors installed as part of the lighting control system are often used to set the occupancy mode of the HVAC system. This type of integration provides for improved efficiency without having to purchase the sensor for both systems.

METHODOLOGY

The goal of utilizing building controls is to measure, monitor, and control, providing data for more efficient and effective operation of the facility. But unfortunately, building controls often do not operate as well as would be desired. There are many reasons for this. Part of it begins with system designers who are more skilled on designing mechanical systems than on controls. It then passes to the contractor who is under pressure to finish the project on schedule and budget, and finally to operators who are often undertrained to utilize these systems. There are numerous programs under way in the industry to help to overcome these issues, improving the quality and performance of these systems.

- Optimization: Properly applied and programmed, building controls can dramatically reduce the energy use of a commercial building. This is done through a series of strategies that start with monitoring and maintaining occupant comfort and Indoor Environmental Quality (IEQ), then moving the minimum amount of air and water to deliver those conditions. Unfortunately, these optimized conditions are often not achieved, due to issues related to the design, poor programming or overrides by the building operator. There are a series of new efforts underway to try to overcome these issues. This includes language in new US energy codes that require optimization, efforts by organization such as ASHRAE to document best practices (ASHRAE Guideline 36 (Guideline 36, 2019)), and work being conducted by the US Department of Energy National Laboratories to create process improvements for the design and delivery of control system sequences called Open Building Control (OpenBuildingControl, 2019). Optimization can be applied both on new buildings as well as retrofitted to existing systems.

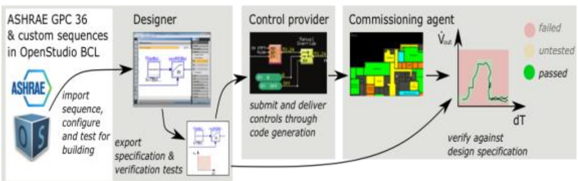

Figure 4: Open Building Control Digital Process Flow

- Semantic Tagging: Control systems are typically designed and installed with a graphical user interface. This interface (typically in a web browser) provides information in a way that allows the user to see the information in semantic context. For example, a floorplan may show the current temperature and setpoint for each room, helping the operator grasp the data and its relationship to the building. When the data for the building is needed for another purpose though, such as analytics or fault detection, the semantic information is hard to determine. The data object for a room's temperature now just says "Room 101" with no context as to what the value is, the room location, or what air handler serves that room. Semantic tagging can provide that additional context, allowing better use of control system data. There are a series of efforts underway to create semantic tagging standards. This includes work from "Project Haystack" (Project Haystack, 2019) and "Brick" (Brick Schema, 2019). Most recently, ASHRAE has partnered with Haystack and Brick to develop an ANSI standard for semantic tagging (ASHRAE Proposed Standard 223, 2018).

- Energy Management Information System (EMIS): Being able to use building control data for applications other than control has the ability to assist operators in making better decisions and improving the operation of the facility. EMIS tools use control system data to provide added processing of data into knowledge. There are many different types of EMIS tools including those that are focused on Energy Information (EIS), Fault Detection and Diagnostics (FDD), and evolving tools that analyze problems and attempt to modify the control logic to resolve the problem called Automated Systems Optimization (ASO). The US Department of Energy is providing a campaign to help educate and promote the use of smart energy analytics (US DOE Smart Energy Analytics, 2019).

- Building to Grid: Programs to allow buildings to participate in demand response programs have been in place for many years. New research is underway to develop models, standards, and programs that will allow buildings to participate in a variety of grid services. This has value in managing the electrical grid for improved resilience and reliability, especially when generating resources are intermittent. The US Department of Energy has a new program focused on efficiency and grid services for buildings called Grid Interactive Efficient Buildings (US DOE, 2019).

- Cyber Security: While building controls are not as critical as control of the electrical grid, they still are responsible for maintaining safety and comfort in critical facilities such as schools, hospitals, and office buildings. Control systems are often network enabled and connected to the Internet which makes them accessible to attackers. There is significant effort ongoing in industry to address the issue of cyber security and to both implement best practices to protect current systems and to develop new, more secure technology.

DISCUSSION AND RESULTS ANALYSIS

The building controls industry is highly consolidated and relatively slow to change and adopt new technologies, however, there are a number of areas of significant innovation that are currently underway. The use of these new technologies is anticipated to have a positive impact on the performance of controls for improved efficiency.

- Model Predictive Control / Artificial Intelligence (MPC / AI): There is significant research and development under way to utilize new technology to improve how well controls work. These new technologies include the use of machine learning and artificial intelligence. For controls, one of the most significant changes is the use of Model Predictive Control (MPC). MPC is a control process based on a mathematical model that can be enhanced over time through observed responses, a process called machine learning. The use of MPC can provide more accurate and efficient control that can balance complex needs such as comfort and efficiency. Currently, these new methods are being used in controls that are integrated into equipment, but new research is underway to include them in applied systems as well.
- Integration: System integration is often considered to be too complicated and expensive to pursue, but the broad use of open standards and solutions such as semantic tagging are driving down the cost and complexity of integrated systems. The driver for expanding systems integration will be energy, but also for improvements in operational efficiency and comfort.
- Comfort management: The building control industry has long been focused on the improvement of the efficiency of commercial buildings. Building owners are now shifting their focus to improving the comfort, and ultimately, the productivity of the building's occupants. Comfort is a complicated topic and is impacted by temperature, humidity, light levels, ventilation, noise, and odors. The perception of comfort also is inconsistent, varying from occupant to occupant. There is more and more interest in the topic of comfort and ventilation, and ideally, a desire to better measure comfort parameters through enhanced sensing and also to deliver comfort on an individual basis.
- Optimized operations / data driven: Building controls have always been focused on safe and efficient operation of equipment along with providing information to the building operator. As the operation of buildings becomes more demanding and more experienced building engineers are retiring and exiting the workforce, there is a need for control systems to provide added support for building operations. One way that this can be done is with new applications which take building control system data and convert it into actionable information. This information can then be used to take actions or be transferred into work order processing systems so that repairs can be scheduled.
- Role of facility management (FM) and Information Technology (IT): There are some similarities in the work required to manage facilities and information technology. Building controls have an even greater synergy since they are computer based and communicate on data networks. Many owners are looking at opportunities to bring these support areas together.

EFFICIENCY CASE STUDY

Davidson College is a small, highly regarded liberal arts college, located just north of Charlotte in Davidson, North Carolina, US. Their sports arena consists of three large sports areas: basketball arena, tennis center and aquatic center. In addition, there are work out rooms, a wrestling room, dance studio, equipment rooms, locker rooms and office space. The basketball arena is used for a wide variety of events including men and women's basketball, wrestling, volleyball and intramural sports. The occupancy of this space can range from a few occupants to as many as 4,800 people during a well-attended basketball game.

Figure 5: Davidson College Belk Arena

The building is approximately 25 years old, and many of the building systems were no longer operating at peak efficiency. Mechanical systems include constant volume, variable volume, and multi-zone air handlers. While the building is only occupied for a part of the day, the mechanical systems were operated continually. All lighting for the building was manually controlled. Central plants for steam and chilled water serve the building. The sports arena, as well as the entire college campus, is connected to an Automated Logic WebCTRL BAS, however the majority of the building controls was the pneumatic system installed in the 1980s and was no longer operating properly.

The sports complex uses campus-provided utilities including electricity, chilled water, and steam. While the owner had installed sub-meters in the building for all of these utilities, the data had not been recorded or stored. This made the calculation of an accurate energy use index for the facility impossible. In order to learn more about the facility, a detailed engineering study was conducted. This included an evaluation of the original design, testing of all systems, and deployment of over 50 data loggers to record temperatures, humidity levels, current draw, and other parameters over an interval of several weeks. The results of this study showed the potential for significant energy conservation measures, which had the potential for both reduced consumption as well as peak demand reduction. The program approved by the owner included:

- Controls Upgrade: Replaced all existing pneumatic controls with a new BAS, providing the owner with the ability to readily manage the building. This also was required in order to deploy the strategies described below.
- Air handler conversions: The original air handling units in the building were designed with fans that operated at a constant speed. These units were retrofitted with variable frequency drives, which allowed for the fan speed to be controlled. Reducing fan speed provided the ability to significantly reduce building peak energy usage. For example, two constant volume fans that together used 16 kW of power originally served the basketball arena and were used for normal operation. The arena also had four larger units, which were used during large events. Abandoning the small units and retrofitting the large units with variable frequency drives reduced fan power to a total of 0.8 kW and still provided the same amount of airflow to the arena.
- Controls optimization: A series of optimization algorithms were deployed. These included resetting pressures and temperatures, scheduling of equipment based on actual occupancy, and controlling unit operation based on building occupancy.
- Lighting control: Occupancy sensors were added for lighting control. A subsequent project also included upgrades to lights in the pool area.
- Project Results: The retrofit project achieved a reduction of peak consumption by over 20 percent (47 kW). Annual energy use (steam, chilled water and electricity) was reduced by over 40%.

An additional case study from the author is available at (Ehrlich, Paul, 2014).

BUILDING TO GRID CASE STUDY

Duke Realty's Towers of Kenwood in Cincinnati Ohio, US consists of two office towers, each about 200,000 square feet, totaling 402,000 gross square feet. The two towers are connected by an atrium. Each of the seven-floor towers provides multi-tenant Class A office space. An in-house team manages the facility. Most of the tenants occupy the building during regular office hours, although a few tenants use the building 24 hours a day.

Figure 6: Towers of Kenwood

The East tower has over 250 water source heat pumps to provide heating and cooling for the building occupants. Each office area has a series of small heat pumps, each with a networked thermostat. This allows each tenant to control the temperature of his or her space. Other mechanical systems in the building include make-up air ventilation units, cooling towers, pumps, and boilers.

One of the central goals of the project was to integrate the building automation system with the utility to support automated demand response capability. Some of the benefits of integration include:

- Real-time information provided to the owner from the main electrical meter about consumption and demand.
- Utility receives additional information about consumption and demand at both the main and sub-meter level for selected areas of the building.
- Demand response signaling – the utility can send the building a signal to reduce demand, and the building can react automatically.

Energy Use and Demand

In 2010, an analysis was completed to benchmark the energy usage of the Towers of Kenwood building with data from the US EIA Commercial Building Energy Consumption Survey 2003 for office space. The analysis found that electrical consumption was about 40 percent higher than the benchmark. Although natural gas consumption was below the average, the total energy cost and usage was more than 25% above the benchmark.

To increase energy efficiency, HVAC equipment scheduling, and thermal loop optimization was implemented. In addition, to reduce peak demand, demand response capability was put in place.

From an energy efficiency perspective, the changes were anticipated to produce a 15% reduction in energy use. At the time of this update, with approximately one year of operation since the retrofits were completed, the building has consistently demonstrated a 16% reduction in energy use relative to the baseline performance established prior to the retrofits. Demand response capability established as part of the retrofit goes beyond mere efficiency to allow the utility to request load reduction to which the building responds automatically in real-time.

Building to Grid

Building to grid connection capability was demonstrated in testing over a period of one week, from June 20 to June 24, 2011 for the East office tower. The five days of experimentation tested four different response levels of increasing severity and a business-as-usual condition. To initiate the testing, the utility sent a demand response signal each day to which the building responded automatically using pre-programmed logic. The building’s demand was monitored to quantify the building’s response.

Upon the utility’s signal to initiate a demand response event, the BAS receives a numerical signal and automatically responds using a pre-defined fully automated algorithm. Table 3-1 shows the four demand response levels and associated behaviors. Based on the level received by the BAS, it in turn communicated the appropriate commands to controllers throughout the building, adjusting temperature set-points and/or controlling water heaters and coolers. The duration of the test events ranged from two to six hours. Average demand reductions ranged from 57 kW to 149 kW, in direct relationship with demand response levels. Feedback from tenants, forewarned of the testing, was limited to the fourth day of testing when the property manager received a complaint that space conditions were uncomfortable.

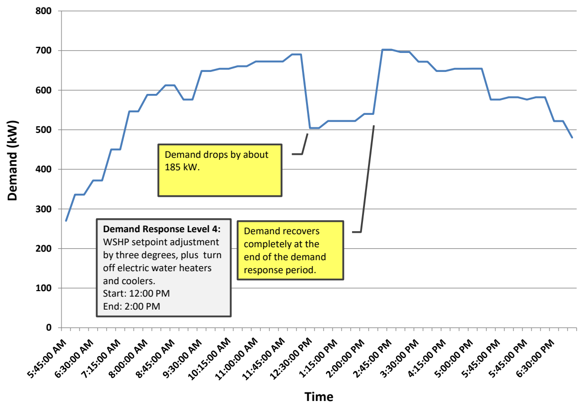

Figure 7: Load profile for Day 4 testing (Thursday)

Technologies Applied to Implement Automated Demand Response

In order to automate demand response, basic infrastructure was installed including communicating meters and an integration gateway. Mechanisms of control and infrastructure for demand response included wireless communicating thermostats, discrete control points and sub-meters.

Water source heat pumps: Wireless thermostats provided the means of control for the water source heat pumps. The BAS communicates setpoint changes to the thermostats based on the demand response signal. The Zigbee wireless thermostats were selected because the installation was greatly simplified relative to using conventional wired communicating thermostats. Each wireless thermostat replaced an existing stand-alone thermostat. Therefore, power wiring already was in place for each thermostat, and communications wiring was not necessary.

Water heaters and coolers: To control the domestic electric water heaters and water coolers based on demand response signals from the utility, a digital output from the BAS in combination with a relay control were employed for each load.

Sub-meters: Beyond this basic infrastructure, sub-meters were installed to monitor various loads in the central plant and on two representative floors by end use. Specifically, the loads included:

- In the penthouse central thermal plant:
  - Loop pumps
  - Cooling tower pumps
  - Cooling tower fans (and VFDs)
- On floors three and four, subpanel loads by end use:
  - HVAC
  - Lighting
  - Plug load

Sub-meters were integrated with the BAS using Modbus, making sub-meter data available to the building operators and managers as well as to the utility.

Demand response testing at Towers of Kenwood implemented and successfully demonstrated the following:

- The use of wireless mesh networking technology to economically connect and enable control of previously independent HVAC equipment.
- The application of micro-load control for demand response, specifically for domestic water heaters and water coolers.
- The ability to shed substantial load on demand in an office-building environment without generally adversely affecting occupant comfort.
- The integration of utility systems with building automation for two-way communication, and the use of building automation and utility information systems to monitor demand response in real time, and to maintain historical data.
- Average demand reductions ranged from 57 kW up to 149 kW, or from 8% to 21% of peak demand, for durations ranging from two to six hours.

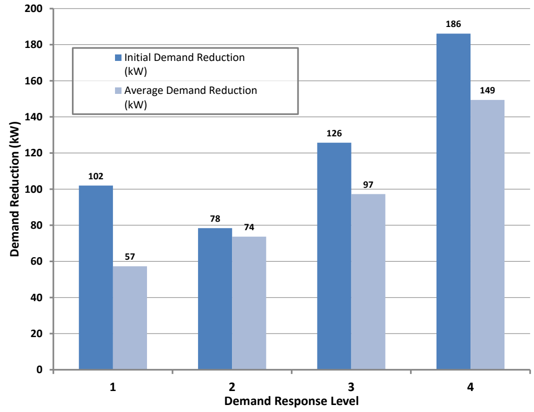

Figure 8: Demand response testing summary

CONCLUSION

Controls, when properly applied can be an important tool to improve energy efficiency and also to support building to grid integration. However, these systems often underperform, largely due to the process challenges in design, installation and operation. Today control products are relatively economical and readily available from global suppliers. There are a number of efforts underway to improve both the process and the technology used in building controls to improve their performance. However, these changes are slow to be adopted and in the meantime building performance suffers. There are several potential solutions to this challenge. One path is to shift building controls to the use of new technologies as identified in this paper. For example, the use of MPC and AI could result in more intelligent systems that would be able to be optimized and require less skill and involvement from designers and installers. The other path is to continue to improve the skill set and processes used for controls systems design, delivery and operation. The new of programs to document best practices (such as ASHRAE Guideline 36) and new digital tools all show great potential. Ultimately the solutions need to build from both of these approaches.

Building to grid integration is still an area that is largely nascent. Programs for shifting demand have been in place for decades but allowing buildings to provide more sophisticated services is slow to evolve. There is great potential in delivering building to grid integration, but work is needed to better understand building physics, occupant comfort, and the economics of grid services to make these programs practical and widely deployed.

REFERENCES

ASHRAE Proposed Standard 223, 2018. [Online]
Available at:
https://www.ashrae.org/about/news/2018/ashrae-s-bacnet-committee-project-haystack-and-brick-schema-collaborating-to-provide-unified-data-semantic-modeling-solution

BACnet International, 2019. [Online]
Available at:
http://www.bacnetinternational.org

Brick Schema, 2019. [Online]
Available at: https://brickschema.org

Ehrlich, Paul, 2014. *Hospital Retrofits for Energy Efficiency.* [Online]
Available at:
https://static1.squarespace.com/static/5bc77901c2ff612eeff9866e/t/5bca13497817f79f2a8d4b2f/1539969866283/30_Ehrlich+Feature+3-14.pdf

Guideline 36, 2019. [Online]
Available at: http://gpc36.ashraepcs.org

LonMark International, 2019. [Online]
Available at: http://www.lonmark.org
[Accessed 2019].

Modbus International, 2019. [Online]
Available at: http://www.modbus.org

N. Fernandez, E. A., 2017. *Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction.* [Online]
Available at:
https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf
[Accessed September 2019].

OpenBuildingControl, 2019. [Online]
Available at: http://obc.lbl.gov

Piette, e. a., 2017. *Demand Response Research Center.* [Online]
Available at:
https://drrc.lbl.gov/publications/2025-california-demand-response
[Accessed 19 November 2019].

Project Haystack, 2019. [Online]
Available at: https://project-haystack.org/

US DOE Smart Energy Analytics, 2019. [Online]
Available at: https://smart-energy-analytics.org

US DOE, 2019. *Grid Interactive Efficient Buildings.* [Online]
Available at:
https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings

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Paul is the founder and President of Building Intelligence Group. He is a licensed engineer and actively involved in efforts to improve building efficiency both on a project-by-project basis as well as programs to elevate the performance of the industry.

Throughout his career, Paul has been actively involved with industry groups focused on the creation of new automation standards and technologies. Previous roles include chairing the ASHRAE BACnet sub-committee on interoperability and acting as the inaugural chair for the oBIX committee to establish XML standards for building controls. He also served two terms as a member of the Electric Power Research Institute (EPRI) advisory council. Currently Paul is a board advisor to the World Orphan Fund and is focused on programs related to development of energy efficiency and clean water.

Prior to forming Building Intelligence Group, Paul spent 20 + years working for industry leading firms including Johnson Controls and Trane. From 2016 – 2018 he served as a program manager and technical advisor at the US Department of Energy's Pacific Northwest National Laboratory.

Paul has a bachelor's degree in mechanical engineering from the University of Wisconsin and a Master of Business Administration from the University of St. Thomas.