DEMONSTRATION OF A LOW COST AUTOMATION OF LIGHTING AS A DEMAND RESPONSE RESOURCE

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ABSTRACT AND KEY WORDS

Lighting, which uses approximately 25 percent of all electricity in commercial buildings[1], may be an effective option for any building management's demand response and load profile strategies. Up to now, the inclusion of lighting into any DR strategy has involved either manually or through a building management system turning off banks of lights. Because there are thousands of individual light fixtures within a building, providing control at each fixture has been expensive because of the need for additional distribution and/or control wiring. With its partners, OSRAM Sylvania, Encore Electronics, EtherMetrics and Consolidated Edison, the Lighting Research Center (LRC) set a goal to develop, demonstrate and evaluate a cost effective, load shedding ballast system including an addressable National Electrical Manufacturing Association (NEMA) Premium instant start ballast, a signaling mechanism to communicate with the ballast and a communication system to connect the load shedding ballast system to the internet or a building's energy management system. Successfully demonstrating such a system allows lighting to be considered as a good candidate for automated demand response programs.

This project has developed a cost effective lighting control and communication system and has demonstrated it can reduce a building's linear T8 fluorescent lighting load by one-third, without reducing building occupants' productivity levels. It has further demonstrated that the aggregation of multiple sites maybe possible to act as one demand response resource and may be able to report back data to meet New York Independent System Operator requirements for spinning reserves. A successful demonstration of the system occurred at five New York sites.

The system has as its core a NEMA Premium load shedding ballast built on an instant start ballast platform that was developed and has been commercialized by OSRAM Sylvania. Communication to the ballast is via a power line carrier signal injected into the line at the lighting distribution panel. No extra communication wiring is required between the numerous ballasts and the lighting distribution panel allowing the system to possess a lower first cost. The communication gateways of the project were provided by EtherMetrics. Via the internet, the EtherMetrics data cube energized the load shedding signal injector and reported back electric loads. Economic payback to the customer is less than three years in parts of New York State for new construction, remodeling and where the customer is replacing older lighting technologies.

KEY WORDS

Demand Response
PowerShed
Load management
Load shedding ballast system
Power line carrier
Spinning reserves
Installed capacity (ICAP)

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[1] United States Department of Energy, U. S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimates. September 2002.

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SUMMARY

Electric grid operators and regulators have a growing interest in demand side curtailment resources, or demand response, to better balance supply and demand in a smarter grid. Similarly, building professionals acknowledge that smarter buildings should have flatter more controlled electrical load profiles. Lighting, which uses approximately 25 percent of all electricity in commercial buildings[2] , may be an effective option for any building management's demand response and load profile strategies. Until recently, the inclusion of lighting into any demand response strategy has involved turning off banks of lights, either manually or through a building management system. The OSRAM Sylvania load shedding ballast system developed during this project demonstrates that lighting can be economically included in many instances as a demand response (DR) resource to manage building peak demands. The automation of the system also allows it to be considered as an ancillary services resource in the future.

The project goals were:

- Develop and test a lighting load-shedding ballast system that is economically justifiable to building owners and non-residential electric customers.
- Develop a communication system that would allow the aggregation of multiple sites with the load-shedding ballast system, meeting the operational requirements of the regional electrical Independent System Operator for the ten-minute spinning reserve, ancillary services electric market or installed capacity market.
- Provide demonstration sites with the ability to control their monthly peak electric billing demands.
- Confirm load reduction amounts when the system is activated.
- Confirm response times from initiation of a load shedding event to the time the lights dim.
- Evaluate building occupants’ satisfaction with lower light levels during times of load shedding.
- Assist in the commercialization of a load-shedding ballast system including the best application fit of the technology.

Through a grant from the New York State Energy Research and Development Authority, the Lighting Research Center and its project partners OSRAM Sylvania, Encore Electronics, EtherMetrics and Consolidated Edison have developed, demonstrated, evaluated and commercialized a load shedding ballast and control system that meets the economic and technical requirements of many building owners and occupants. The core of the load shedding ballast system is a highly efficient, low cost, step dimming ballast that, when activated, will reduce power and light output by one-third. To keep the load shedding ballast system costs low, a power line carrier (PLC) signaling system is employed to communicate with individual ballasts. This eliminates the need for additional control wiring or expensive wireless communications. The PLC is injected into the neutral wire at a distribution power panel using a

[2] United States Department of Energy, U. S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimates. September 2002.

simple signal generator, amplifier and signal coupler, together the signal injector. The ballast and control signal devices were designed, built and commercialized by OSRAM Sylvania. In four of these demonstrations, the signal injector is turned on and off via a gateway communication device provided by EtherMetrics. It is connected to the internet or the building's energy management system. The load shedding ballast system can be automated to respond to the building's peak electric demand, a utility's need to reduce loads, or in response to an independent generation and transmission system operator or utility declared demand response events. If the building does not have a building management system, the Ethermetircs data cube and web server can act as an inexpensive alternative, controlling peak electric building demands through a cloud computing application.

Five demonstration sites were chosen to demonstrate the load shedding ballast system and to evaluate the technical merits of the system, as well as building occupants' acceptance of dimming lights for short periods of time (two hours at a time, multiple times, over varying times of the day). These sites include:

- a library at Yeshiva University, New York City
- two offices of the City of New York, New York City
- an office at Columbia University, New York City
- a manufacturing facility of Welch Allyn, Scaneateles Falls, New York

The average measured load reduction when the load shedding ballast system was activated was 30 percent of the full load lighting wattage. The anticipated load reduction is 33 percent. The measured load reductions are quite similar to the anticipated one-third reductions given there are other transitory loads included in the data that were gathered. It is safe to say the load shed ballast system achieved the desired load reductions.

Illuminance reductions in areas where the load shedding ballast system were installed and in operation were approximately 33 percent if the space was away from windows. This matches the anticipated illuminance reductions. Near windows where daylight was present, the illuminance reductions were less than 33 percent because of the contributions from daylighting.

Two surveys were used to measure building occupant acceptance of the load shedding ballast system. The first survey was completed prior to the load shedding ballast system being activated. This allowed researchers to determine building occupant satisfaction with the existing lighting at full light output. A second survey was conducted with the load shedding ballast system energized (illuminance reduced by one-third). The key question on the surveys asked how well building occupants could see to do their work. Any reduction in productivity would be a detriment to the load shedding ballast system's practicability. Table 1 below illustrates building occupant responses at the five demonstration sites to the key question on the ability to see.

Table 1: How well can building occupants see to do their work?

	Full Light Output	Lights Dimmed by Load Shed System
Number of Respondents	113	88
Very Poorly	2%	0%
Poorly	6%	8%
Neutral	16%	21%
Well	51%	56%
Very Well	25%	15%

The results indicate there is very little change in building occupants' perceptions on how well they can see to do their work between the full illumination case and when the lights are dimmed by the load shedding ballast system. Of the five demonstration sites, Welch Allyn was an outlier. For Welch Allyn, the load shedding ballasts were located within a space where precision machining to very close tolerances is required. The negative visual capabilities of building occupants caused by the one-third reduction in illuminance were significant in a setting where critical visual tasks are being performed and the full lighting output only meets minimum recommendations. The load shedding ballast system probably should not be used where critical visual tasks are required.

One of the project's goals was to determine if the load shedding ballast system could be used as part of the spinning reserves in ancillary services electric markets. It may be possible in the future for the load shedding ballast system to be included in the ancillary services market. However, certain reporting criteria requirements cannot be met currently. The viability of the load shedding ballast system use in spinning reserve markets is minimized because of the small size of the load reduced, the acceptability of lighting to follow the loading demands of ISO (having the lighting illuminance increase or decrease possibly every six seconds to meet ISO load projections) and the variability in reporting reductions in lighting loads due to other loads being on the same data collection system.

The ability to accurately measure the amount of demand response achieved at a site may be an issue since electrical loads vary. Measurement at the demonstration sites showed varying loads being reported every five seconds. Only an estimate of the amount of load reduced by activating the load shedding ballast system was achievable.

The economics of installing the load shedding ballast system have to provide a reasonable return on the building owner's investment. The quickest return is through limiting the building's monthly peak electrical demand. Currently, the best economic returns will occur where billing demand charges are high such as New York City and southern California. To assist building owners and OSRAM Sylvania in determining costs and benefits, the Lighting Research Center with assistance from the New York State Energy Research and Development Authority developed an economic calculator.

Base on the results from the demonstration and evaluation of the load shedding ballast system, the following conclusions are made.

- A cost effective (for new construction and replacement of inefficient lighting systems) load shedding ballast system was developed and is commercialized including a high efficiency load shed ballast, a power line carrier signaling device and a communication gateway.
- The power line carrier signaling method to each ballast proved to be effective with no interference to other electronic devices.
- Equipment installation of the load shed ballasts were observed to take the same amount of time as any other ballast installation. The installation complexity of the signal injector is dependent on the installation site specifics.
- The wiring terminal device within the signal injector where the incoming power is terminated should be changed to accommodate larger wire sizes.
- The operation of the load shedding ballast system through the internet, where either a building management system (BMS) is not present or not feasible, is straight forward and easy. Once the secure EtherMetrics server is accessed, one click of the mouse turns the system on or off. The use of outbound only communications between the communication gateway and the server allowed for passage through demonstration site firewalls. The EtherMetrics DataCube and server are inexpensive alternatives for a BMS.
- The measured load reduction achieved by the load shedding ballast system was close to the anticipated load reductions.
- Illuminance level reductions were also near anticipated levels when the load shedding system was in operation.
- Occupant acceptance of the load shedding ballast system in terms of perceptions of light quality and quantity were satisfactory to conclude the load shedding ballast system will not adversely affect occupants' productivity in most instances.
- Where critical visual tasks are performed, the load shedding ballast system should not be installed.
- The fastest return on the customer's investment in the load shedding ballast system is provided by reducing the building's peak monthly electrical billing demand.

Section 1

INTRODUCTION AND BACKGROUND

The Federal Energy Regulatory Commission[3] , U. S. Department of Energy[4], National Association of Regulatory Utility Commissioners[5], New York Independent System Operator (ISO) and others have stated an effective open market for electricity *must* be balanced with both generation and demand response (DR) in the capacity and ancillary services markets. The North American Electric Reliability Council (NERC), the organization charged with ensuring a reliable electric system, has gone further in its *2006 Long Term Reliability Assessment Report* insisting the future reliability of the North American electric system is partially dependent on the enactment of effective DR programs[6].

In New York State, utilities and the independent system operator with assistance from NYSERDA have established a series of DR programs to balance electricity markets, match electric loads with supply and defer additional capacity needs. Other states and regions have enacted similar DR programs. These programs (listed below) provide monetary compensation to customers who participate.

- Voluntary DR programs - In New York, the Emergency Demand Response Program fits into this category. Program operation is initiated by the independent system operator when there is the potential for electric demand to exceed supply including reserve requirements. Customers who have enrolled in the program reduce load, if possible, when called upon. Usually a minimum of one to two hours notification is given to the customer to reduce load. A major difference between voluntary and electric market programs is usually there are no penalties if the customer does not perform in the voluntary programs. Customers usually enroll through a third party aggregator.

- Open electric market DR programs - Many independent system operators (ISOs) have established DR programs that can compete with generation in the open electric markets. These programs include installed capacity (ICAP), day ahead DR and demand side ancillary services. All of these DR programs must be bid into the electric market and compete, based on price, with generation. If the ISO selects a DR resource to participate and if called upon to perform, the customer must reduce load within the given amount of notification time and report back performance in accordance with the rules of the electric open market program for which they have bid in their load. There are monetary penalties for non-performance. Each electric market DR program has

[3] Federal Energy Regulatory Commission, Assessment of Demand Response and Advanced Metering Staff Report Docket Number AD-06-2-00. August 2006.

[4] United States Department of Energy, Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them. A Report to Congress, Pursuant to Section 1252 of the energy Policy Act of 2005. February 2006.

[5] Katham, D., ICF Consulting, Policy and Technical Issues Associated with Independent System Operators Demand Response Programs. Prepared for the National Association of Regulatory Utility Commissioners, July 2002.

[6] North American Electric Reliability Council, 2006 Long Term Reliability Assessment Report. October 2006.

different response and reporting criteria. For example, the demand side ancillary services ten-minute spinning reserve program requires the customer to reduce loads within ten minutes and report load reductions at specified intervals. Customers usually enroll through a third party aggregator.

Another potential revenue stream for customers installing DR equipment is reducing the monthly billing demand charged by electric utilities. Demand charges are incurred for the highest 15 or 30 minute use during the month. It reflects the cost of providing distribution and transmission capacity such as transformers, distribution circuit wiring, etc. to meet the highest load the customer imposes on the utility system.

Lighting, which represents 25% of electric use in commercial buildings[2], may be an effective option for any building management's demand response and load profile strategies. It is too large of a load to be ignored. Until recently, the inclusion of lighting into any DR strategy has involved turning off banks of lights, either manually or through a building management system. Because there are thousands of individual light fixtures within a building, providing control at each fixture has been expensive because of the need for additional distribution and/or control wiring.

Surveys conducted by the LRC[7] indicate the customer's primary need when making improvements to their lighting system or adding lighting controls is to receive a reasonable return on their investment. Therefore, the load shedding ballast system must provide that reasonable return if it is to be successfully marketed. Reasonable returns require low material and installation costs and high income streams or the avoidance of electrical supply costs such as reductions in monthly demand charges.

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[7] Lighting Research Center, Energy-Efficient Load-Shedding Lighting Technology Final Report. Prepared for the California Energy Commission. January 2005

Section 2

TECHNOLOGY DEVELOPMENT

The LRC partnered with OSRAM Sylvania (OSI), Encore Electronics and EtherMetrics to develop the load shedding ballast system including the ballast, a signaling mechanism to communicate with the ballast and a communication gateway system to connect the load shedding ballast system to the internet or a building's energy management system.

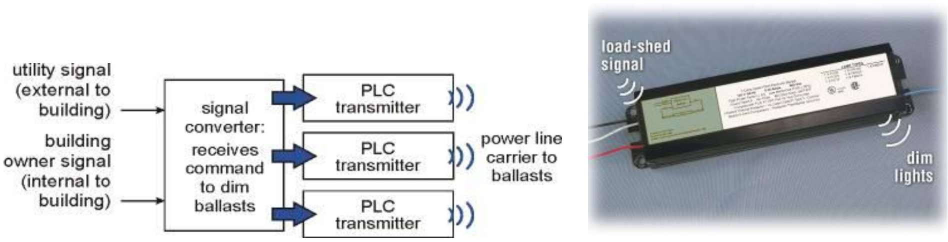

Figure 1: Diagram of the Load Shedding Ballast System

LOAD SHED BALLAST DEVELOPMENT

The LRC developed prototype load shedding ballasts that utilized switches to place capacitors in line with fluorescent lamps to reduce lamp currents and power to the lamps. The switching mechanism allowed for ramp dimming of the lamp output. OSI examined the prototype design and deemed it too costly to include in the final ballast design. The ramp dimming doubled the incremental cost of the load shed ballast. OSI elected to use step dimming, a lower cost alternative.

The one-third reduction in power and light output was developed through LRC testing of lamp life and building occupant acceptance of reduced illuminance levels. The LRC discovered that the one-third dimming level without providing external heating of the electrodes did not affect lamp life[8]. Also, 70 percent of subjects in a human factors experiment found the one-third reduction in illuminance acceptable to maintain work output for short (up to two hours) periods of time[9]. The LRC logged over 40,000 hours of lamp operation on ten lamps at the one-third dimming level without any lamp failures. OSI is conducting their lamp life tests with their PowerShed® ballast to

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[8] Garza, F. A Study of Cathode Fall Voltage and Lamp Life of T8 Instant-Start Fluorescent Lamp Systems Under Low Lamp Current Conditions. Rensselaer Polytechnic Institute, Troy, NY, July 2003.

[9] Akashi, Y andNaches, J. Detectability and Acceptability of Illuminance Reduction for Load Shedding. IESNA Annual Conference Proceedings, August 3-6, 2003.

determine warranty information. OSI currently warranties the lamps for full life if the load shedding ballast system is used no more than 200 hours per year.

The LRC also explored means to communicate with the load shed ballast. A power line carrier system (PLC) was deemed the most reliable with the lowest cost. Both amplitude and frequency modulation prototypes were developed and tested. Both systems worked; however, OSI developed their own signaling system based on a simple concept of a tone placed on the neutral wire of the distribution system. The ballast contains a receiver tuned to the frequency of the tone. If the frequency is detected at a minimum amplitude, the receiver closes a switch within the ballast that places a capacitor in line with the lamp causing lamp current to decrease.

The ballast is based on a NEMA Premium, instant start ballast. This is the least costly, most efficient, most widely used electronic ballast for operation with T8 lamps.

SIGNAL INJECTOR

OSI refers to the commercialized signal injector as the Command Injector®.

The LRC developed a prototype PLC signal injector consisting of a signal generator, an audio amplifier and injection coil placed around all three phase wires and the neutral. The signal injector was to be placed at the power distribution panel which would always be on the secondary side of any power transformer. PLC signals do not normally pass through transformers. This design was passed on to Encore Electronics to further develop the product based on OSI specifications. The Encore beta version allowed for operation with either 120 volt or 277 volt distribution systems. It created a 20 kHz signal of sufficient amplitude to capture the ballast receivers before reducing signal strength to minimum levels to retain reception. The Encore version was tested by the LRC and OSI. The LRC tested for interference with other electric office devices like computers, copiers, sensitive laboratory equipment and printers. No interference was found. OSI performed a multitude of tests including harmonic tests required by the Federal Communications Commission (FCC) of any device that transmits a signal. OSI discovered high harmonics levels emanating from the Encore device. At these levels, the Encore signal injector would not pass FCC requirements[10].

OSI decided to develop their own signal injector design which could pass UL and FCC requirements. The signal output of the OSI designed signal injector is a tuned circuit requiring impedance matching with the injection coil or coupler. When impedance is matched, signal strength is maximized without producing harmonics of the primary frequency of 20 kHz. Matching impedance is achieved by changing the number of primary wire turns on the ferrite coupler. The LRC used an oscilloscope to ensure maximum signal output for each of the five signal injectors installed at the demonstration sites. The LRC also tested the OSI designed signal injector for interference with other electric office devices. No interference was found.

[10] Title 47, FCC Regulations, Part 15, Radio Frequency Devices, Subpart R, Intentional Radiators.

OSI has branded its signal injector and coil as the Command Injector® and Command Coupler®, respectively. A photo of the Command Injector® and the EtherMetrics communication gateway are found in Figure 2.

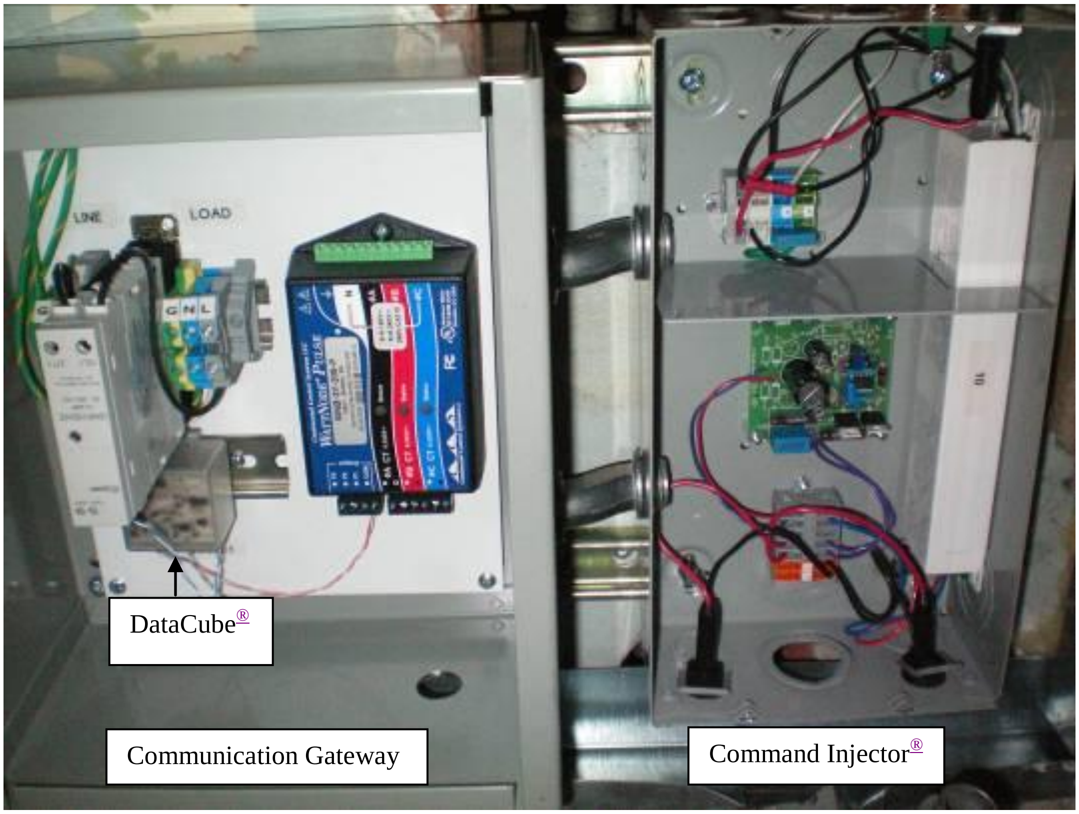

Figure 2: Command Injector® and Communication Gateway

COMMUNICATION GATEWAY

The project needed an inexpensive communication device to remotely and automatically control the load shedding ballast system from a building management system or an internet server located off site. The original communication manufacturing partner, Connected Energy, was sold prior to the need for the communication gateway equipment. The new owners did not have an interest in participating in the load shed demonstration projects. Therefore, the LRC, with assistance from NYSERDA, sought and found a different manufacturer, EtherMetrics, LLC. EtherMetrics has developed a data collection and control module which can communicate over internet wiring or twisted pair cable using many different communication protocols. It utilizes open architecture software which makes communicating with the device very flexible. The DataCube® was originally developed to provide data collection and energy monitoring functions. However, it does have a built in low power relay that can provide a control function. The combination of control and data collection functions, along with low cost, attracted the LRC to use the EtherMetrics technology.

The DataCubes® used for the demonstration projects receive power over the ethernet. A second power option is an external power source if ethernet power is not available. The project DataCubes® are connected to the internet via CAT5 wiring and the local area network. Because the DataCube® communication is outbound only to the EtherMetrics server, getting permission to traverse demonstration site firewalls was not an issue.

The DataCubes® at the demonstration sites control a solid state power relay that turns the signal injector on and off. It also collects pulse data from a watt-hour meter also provided by EtherMetrics. This data was used to measure building electrical demands and demonstration location power distribution panel electrical demands so an estimation of power reductions caused by the load shedding ballast system could be measured. Data collected by the DataCube® is transmitted via the internet to the EtherMetrics server where reports and data analysis can be performed.

The EtherMetrics DataCube® placed at the main electric meter and its remote server allow the building owner to possess a simple, low cost building management system that can control the entire building peak electrical demand and collect data on the entire building electrical load. The process can be automated by establishing demand limits for each month and having the server monitor demands and turn on the load shedding ballast system when the demand limit is approached. Multiple building aggregation can also occur at the EtherMetrics' server allowing curtailment service providers and building owners simple, low cost control of curtailable lighting loads.

POWERSHED® RELAY

In a separate project, OSI developed a relay device that can control other lighting and non-lighting loads utilizing the same signaling system as the load shed ballast. If other loads are included on the same electrical distribution panel where the signal injector for the load shed ballasts is installed and the PowerShed® relay is attached to these loads, these loads will receive the same signal and can be turned on or off or reduce their power use. The PowerShed® relay is equipped with the same receiver as the load shed ballast and both a normally closed and normally open low current relay. These relays can interrupt control circuits on heating, ventilation and air conditioning equipment or power to lighting fixtures to allow for increased demand response with very little additional cost.

Figure 3: PowerShed® Relay

Section 3

DEMONSTRATION SITES AND EQUIPMENT INSTALLATION

Five demonstration sites were included as part of the project. Four of the sites are located in New York City and the fifth site is in Scaneateles Falls, New York.

DEMONSTRATION SITES

Yeshiva University, Mendel Gottesman Library

Figure 4: Yeshiva University Mendel Gottesman Library

A library stack area and a study area on the third floor were selected for the demonstration of the load shedding ballast system.

Figure 5: Demonstration Areas within Mendel Gottesman Library at Yeshiva University

Original Lighting System:

- Stack Area: Combination of two-lamp, three foot (25 watt) and four foot (32 watt) light fixtures using T8 lamps and first generation rapid start electronic ballasts. Total of 59 fixtures.
- Study Area: Three-lamp (32 watt) T8 light fixtures with first generation rapid start electronic ballasts. Total of 41 fixtures
- Total wattage – 7.05 kW

Load Shedding Ballast System:

- Stack Area: Combination of two-lamp, three foot (25 watt) and four foot (28 watt) light fixtures using T8 lamps and load shed NEMA Premium instant start electronic ballasts. Total of 59 fixtures
- Study Area: Three-lamp (28 watt) T8 light fixtures with load shed NEMA Premium instant start electronic ballasts. Total of 41 fixtures
- Total wattage – 5.35 kW
- Wattage shed when load shedding system is energized – 1.77 kW

City of New York, 1 Centre Street, 15th Floor Offices:

Figure 6: 1 Centre Street Building and Demonstration Area

Both private and open office space lighting in the management information systems department were used in the demonstration. Much of the demonstration space on the 15th floor is near windows. The presence of daylight assists in overcoming any issues with illuminance reductions when the load shedding ballast system is energized.

Original Lighting System:

- Three-lamp, 32 watt, T8 direct/indirect fixtures with older instant start electronic ballasts. Total of 100 fixtures.
- Total wattage – 9.0 kW

Load Shedding Ballast System:

- Three-lamp, 32 watt, T8 direct/indirect fixtures with load shed NEMA Premium instant start electronic ballasts. Total of 100 fixtures.
- Total wattage – 8.2 kW
- Wattage shed when load shedding system is energized – 2.7 kW

<u>City of New York, 1 Centre Street, 19th Floor Offices:</u>

Similar to the 15th floor, both private and open office space lighting in a section of the Department of Citywide Administrative Services were used in the demonstration. Much of the demonstration space on the 19th floor is also near windows. The presence of daylight assists in overcoming any issues with illuminance reductions when the load shedding ballast system is energized.

Original Lighting System:

- Three-lamp, 32 watt, T8 direct/indirect fixtures with older instant start electronic ballasts. Total of 80 fixtures.
- Total wattage – 7.2 kW

Load Shedding Ballast System:

- Three-lamp, 32 watt, T8 direct/indirect fixtures with load shed NEMA Premium instant start electronic ballasts. Total of 80 fixtures.
- Total wattage – 6.56 kW
- Wattage shed when load shedding system is energized – 2.16 kW

<u>Columbia University, 545 West 112th Street, Offices</u>

Figure 7: Columbia University Building and Demonstration Area

Private and open space offices and common areas located on the fourth floor were used in the demonstration. The west, south and north side office spaces are exposed to daylight. The presence of daylight assists in overcoming any issues with illuminance reductions when the load shed ballast system is turned on.

Original Lighting System:

- Combination of two and three-lamp, 32 watt, T8 parabolic fixtures with older instant start electronic ballasts. Total of 100 fixtures.

- Total wattage – 7.32 kW

Load Shedding Ballast System:

- Combination of two and three-lamp, 32 watt, T8 parabolic fixtures with load shed NEMA Premium instant start electronic ballasts. Total of 100 fixtures.

- Total wattage – 7.03 kW

- Wattage shed when load shedding system is energized - 1.84 kW

<u>Welch Allyn, Scaneateles Falls, Tool Machining Room</u>

Figure 8: Welch Allyn Building and Demonstration Area

The tool room is an interior space with no windows. Very close tolerance machining is performed within the space. The quantity and quality of lighting is extremely important. Illuminance measurements with the load shed ballast at full light output indicated minimum recommended illuminance requirements were being met for this type of space.

Original Lighting System:

- Four lamp, 34 watt, T12 prismatic fixtures were used with two magnetic ballasts. Total of 100 fixtures
- Total wattage – 12.0 kW

Load Shedding Ballast System:

- Three-lamp, 32 watt, T8 prismatic fixtures with the load shed NEMA Premium instant start electronic ballast is in use. Total of 100 fixtures.
- Total wattage – 8.2 kW
- Wattage reduced when system is turned energized – 2.7 kW

EQUIPMENT INSTALLATIONS

The load shed ballast installation is the same as any other instant start electronic ballast. Replacing existing rapid start and instant start electronic ballasts and magnetic ballasts at the five demonstration sites did not present any issues for the qualified electricians that performed these tasks. Average time to exchange the original ballast with the load shed ballast was observed to be 15 to 20 minutes. This time includes moving a ladder in place, removing lamps, opening the ballast channel, removing the existing ballast, and wiring in the new load shed ballast, replacing the ballast cover and lamps and closing the fixture lens. With the exception of fixtures in the study area of Yeshiva University's library, all fixtures were mounted no higher than ten feet above the floor. The study area fixtures are approximately 20 feet above the floor, requiring scaffolding to be erected at the beginning of the work.

Figure 9: Light Fixture and Ballast Installation

Installation of the Sylvania Command Injector® and Command Coupler® and the EtherMetrics gateway data collection and communication devices differed greatly from site to site. All five demonstration sites required installing the injector, coupler and gateway into existing distribution panel locations. Where the distribution panel was located in areas with plenty of room surrounding the panel, the installation of all three devices is straightforward and no installation issues were encountered. Welch Allyn's installation (Figure 10) and Yeshiva University fell into this category. Installation times were approximately one to two hours.

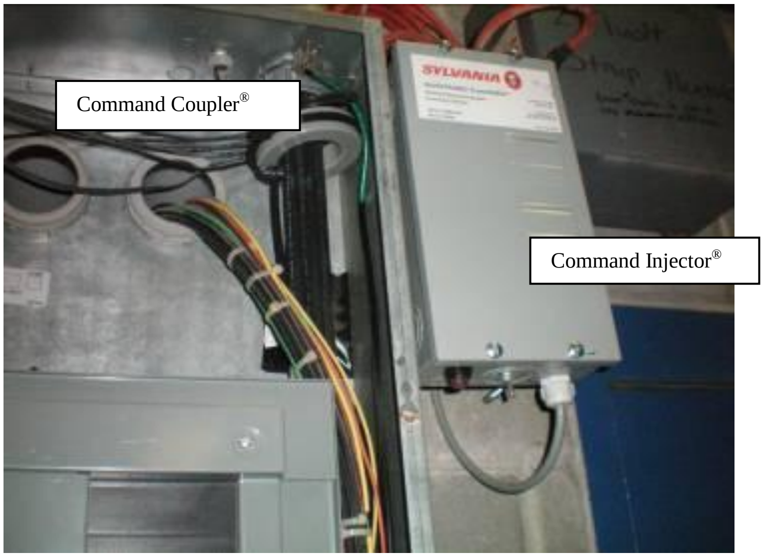

Figure 10: Command Injector® and Command Coupler® Installation at Welch Allyn

The other three demonstration sites, where space near the electrical distribution panel was limited, required placing the Command Injector® and communication gateway somewhat remote from the distribution panel. Wiring these devices to the Command Coupler® and power source required additional installation time. At 1 Centre Street, the Command Injector® and gateway had to be placed in a different electrical closet from the lighting distribution panel where the coupler was located. Installation times were approximately three hours. At Columbia University, the Command Injector® and gateway were placed on an interior wall and wiring had to be routed to the lighting distribution panel. Installation time was also approximately three hours.

The installation directions provided by Sylvania were reviewed with the electricians. In all cases, the instructions were viewed as adequate to properly install the Command Injector®.

Based on installation observations, it is recommended that the wiring block where the power enters the Command Injector® be changed to one that can handle larger wire sizes (see Figure 11 below). Electricians had a difficult time trying to fit 12 AWG solid wire sizes into this wiring block. Power for the Command Injector® comes from the lighting panel it controls. Most circuit breakers in these panels are 20 amps; therefore, wires emitting from these breakers must be rated for 20 amps.

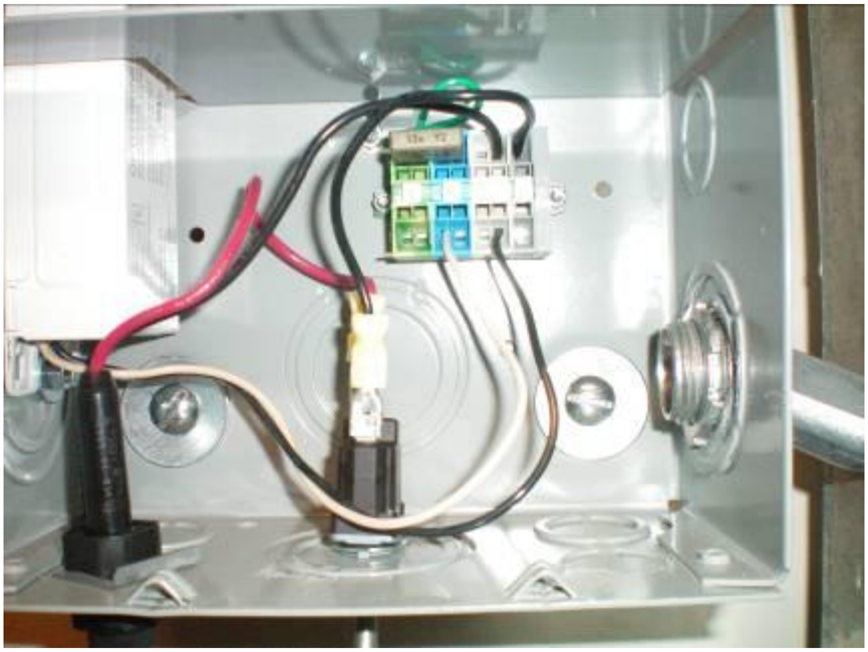

Figure 11: Wiring Block within the Command Injector®

At Columbia University, the load shed operation did not work after the installation was complete. Troubleshooting the installation required an additional two hours to discover the issue and correct the situation. The power distribution panel is a feed through panel. The main electrical wires enter the panel and a second set of wires exits the panel to feed additional electrical panels in different parts of the building. The wires both entering and exiting the panel are identical. Determining which set of wires feeds (enters) the distribution panel where the load shed ballasts have been installed is difficult. During preliminary testing, LRC personnel installed the Command Injector® on one set of wires. As was later shown, these were the exiting wires and not the entering wires. Because the power line carrier signal only travels outward to the load shed ballasts, placing the Command Coupler® on the wrong set of wires caused the shed signal to only travel to ballasts that were not part of the demonstration project and were not load shed ballasts. Changing the Command Coupler® to the incoming (entering) wires solved the problem. All load shed ballasts now responded to the power line carrier signal.

Section 4

DEMONSTRATION SITE FIELD EVALUATIONS

EASE OF OPERATION

Operation of the system has been made easy through the use of EtherMetrics' communication gateway and web server. The screen developed by EtherMetrics is easy to use and records all events, electrical demands at the distribution panel and, in some cases, the building's electrical demand. Figure 12 below depicts the EtherMetrics computer screen that is used to control the load shedding ballast systems at 1 Centre Street. The same screen is used for control at Yeshiva University and Columbia University. Welch Allyn has the ability for the Command Injector® to be controlled by their building management system.

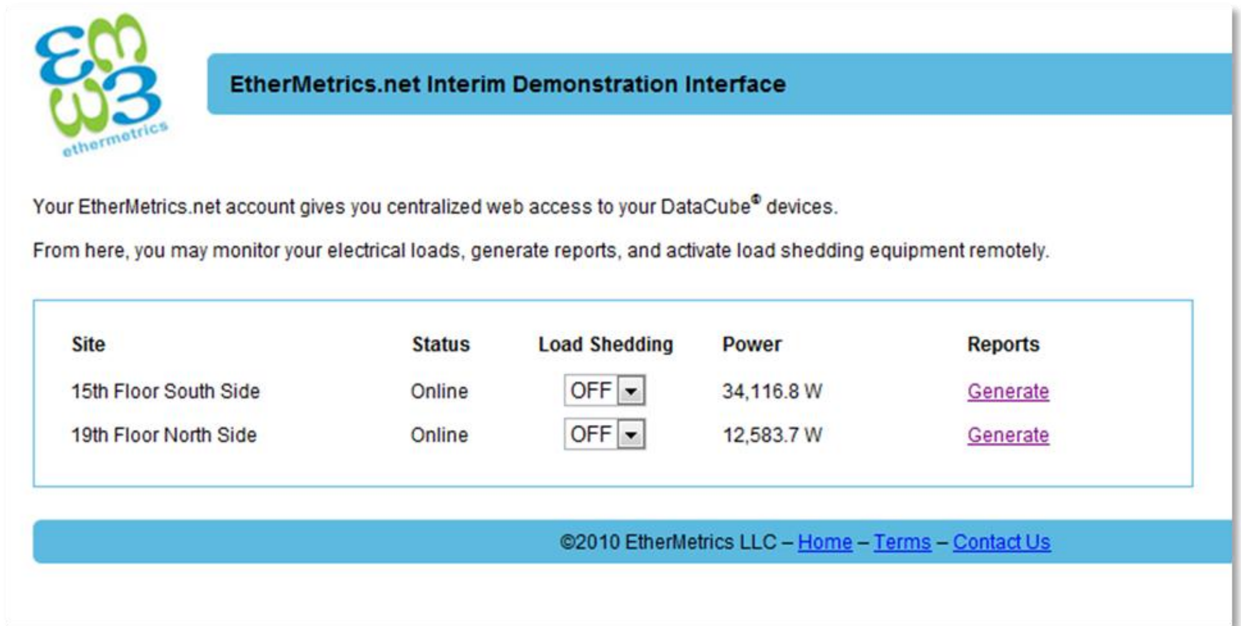

Figure 12: EtherMetrics Control Screen

The operator must have access to the internet and the password-protected EtherMetrics web site. Once the control screen is accessed, the operator can choose which of two methods they want to control the load shedding ballast system. The operator can elect to override the system by clicking the on/off button provided and turn the system either on or off. The second method of controlling the load shedding ballast system through an energy management function was not demonstrated, but is possible. The operator programs the desired maximum building demand that they do not wish to exceed. The EtherMetrics server counts the pulses from the building's electric meter that represents the current electric demand. If the pulses exceed the desired maximum building demand, the EtherMetrics server automatically energizes the load shedding ballast system. The load shedding ballast system stays on for a minimum of 30 minutes to eliminate any short cycling of the lighting system. If the building electric demand is below the set value at the end of the 30 minutes, the load shedding ballast system is turned off.

The control of the system can be anywhere in the world, as long as the operator has access to the internet and has the correct password. All that is required is a mouse click to activate the system. Experiences by LRC and demonstration site personnel confirm the ease of operating the system. The LRC exercised the system from remote locations while demonstration site personnel operated the system from on-site. Response time from the click of the mouse to the dimming of the lights was observed at five seconds at the four sites connected to the EtherMetrics server.

ACTUAL VERSUS ANTICIPATED LOAD SHED CAPACITY

The anticipated power reduction from the load shedding ballast system is one-third of the full lighting load. For example, the City of New York – 15th Floor location has 100, three T8 lamps light fixtures each with a load shed ballast. Each fixture, at full power, uses 82 watts. When in the load shed mode, a reduction of one-third of the 82 watts, or 27 watts, is anticipated. For all 100 fixtures, the anticipated power reduction is 2.7 kilowatts (kW).

The measured power reductions were achieved using the EtherMetrics data acquisition system for all sites except Welch Allyn. Readings from the EtherMetrics system just prior to the system being energized or just after it was de-energized were used to establish the power demand with the load shedding system off. A second set of readings just prior to the load shedding system being de-energized or just after the system was energized were used to determine the load on the distribution panel with the lights in the dimmed mode. The difference in these readings was used to estimate the amount of load shed by the load shedding ballast system. The Welch Allyn site does not have the EtherMetrics data collection system. At this site, data was collected using a clamp-on ammeter. The systems were exercised multiple times and the average of all readings was used to estimate load reductions. Table 2 below illustrates the anticipated load reduction compared with the measured load reductions.

Since the electrical distribution panels at all sites include lighting and plug loads beyond just the load shed ballast lighting, it is impossible to measure only the power going to the load shed ballast lighting. Because of the mixed loads being measured and their transitory nature, it is impossible to accurately measure just the load shift when the load shed ballasts are turned on or off. However, a good approximation is possible using the data collection system.

Table 2: Anticipated versus Measured Load Reductions

	Yeshiva University		City of New York- 15th Floor		City of New York- 19th Floor		Columbia University		Welch Allyn
Anticipated Load Reduction	1.78 kW		2.7 kW		2.16 kW		1.84 kW		2.7 kW
Measured Load Reduction	1.76 kW		2.68 kW		1.98 kW		1.95 kW		2.35 kW

The measured load reductions are quite similar to the anticipated one-third reductions given there are other transitory loads included in the data that was gathered. It is safe to say the load shedding ballast system achieved the desired load reductions.

Illuminance Level Reductions

Besides reducing power needs by one-third, the load shedding ballast system will reduce illuminance by one-third. Illuminance measurements at each site were taken with a calibrated, hand-held illuminance meter with the lights at full output and when the load shedding ballast system was activated. In some instances like the City of New York and Columbia University, the existence of windows and presence of daylight assists in maintaining higher lighting levels than anticipated, even with the load shedding ballast system in operation. This is especially true for an exterior office at the City of New York, 19th Floor site with southwest facing windows where the illuminance reading with the load shedding ballast system on was taken in the later afternoon while illuminance readings with the system off were taken earlier in the day.. The illuminance reading actually increased. No illuminance readings were taken of the City of New York, 15th Floor site.

Table 3 illustrates the light levels under normal and load shed lighting conditions.

Table 3: Illuminance Reduction caused by the Load Shedding Ballast System

	Normal Lighting Conditions	Load Shed Dimmed Conditions	Percent Reduction
City of New York, 19th Floor			
Interior Open Office 1	476 Lux	396 Lux	16.8%
Interior Open Office 2	468 Lux	308 Lux	34.2%
Interior Open Office 3	340 Lux	280 Lux	17.6%
Exterior Private Office, southwest exposure	974 Lux	1176 Lux	+20.7%
Yeshiva University Library			
Stack Area 1 Horizontal	339 Lux	240 Lux	29.2%
Stack Area 1 Vertical	245 Lux	164 Lux	33.1%
Stack Area 2 Horizontal	441 Lux	295 Lux	33.1%
Stack Area 2 Vertical	177 Lux	145 Lux	18.1%
Study Area 1	815 Lux	523 Lux	35.8%
Study Area 2	726 Lux	486 Lux	33.2%

Welch Allyn			
CNC Machine	733 Lux	465 Lux	36.6%
CNC Machine with Task Light	1290 Lux	1040 Lux	19.4%
Isle way	1365 Lux	895 Lux	34.4%
Work Bench	711 Lux	563 Lux	20.8%
Columbia University			
Interior Open Office	620 Lux	445 Lux	28.2%
Copy Machine Area	679 Lux	481 Lux	29.2%
Exterior Office South Exposure	667 Lux	524 Lux	21.4%

Building Occupant Acceptance of the Load Shedding Ballast System

Two surveys were used to measure building occupant acceptance of the load shedding ballast system. Because the system dims the lights by one-third when it is in operation, it is important to determine if building occupants accept this lower light level. Any measurable reduction in occupant productivity would negatively affect the use of the load shedding ballast system. The first survey was completed prior to the load shedding ballast system being activated. This allowed researchers to determine building occupant satisfaction with the existing lighting at full light output. A second survey was conducted with the load shedding ballast system activated. These surveys were conducted approximately one to two hours after the lights were dimmed. Sample survey documents are included in Appendix A. The two City of New York sites, Welch Allyn and Columbia University, are considered within-participant surveys. Yeshiva University is a between-participant survey. Table 4 presents the results from the surveys at individual demonstration sites. Table 5 presents the aggregated results of all surveys from all sites looking at five key questions: how much occupants like the lighting in the area, how comfortable the lighting is, how bright the area is, how well occupants can see to perform tasks and did occupants see the lights dim.

Table 4: Individual Site Results: Occupant Acceptance of Load Shedding Ballast System

	Yeshiva University		City of New York 15th Floor		City of New York 19th Floor		Columbia University		Welch Allyn	
	Load Shed Off	Load Shed On	Load Shed Off	Load Shed On	Load Shed Off	Load Shed On	Load Shed Off	Load Shed On	Load Shed Off	Load Shed On
# Respondents	25	4	23	18	36	34	23	26	6	6
Do you like the lighting in the area?										
Dislike very much	10%	0%	0%	6%	3%	0%	13%	0%	0%	0%
Dislike	5%	25%	4%	5%	0%	6%	13%	31%	0%	50%
Neutral	52%	50%	39%	55%	25%	23%	44%	38%	0%	33%
Like	29%	25%	39%	28%	53%	56%	26%	27%	17%	17%
Like very much	4%	0%	18%	6%	19%	15%	4%	4%	83%	0%
How comfortable is the lighting?										
Very uncomfortable	14%	0%	0%	6%	0%	0%	17%	0%	0%	0%
Uncomfortable	10%	25%	13%	11%	3%	6%	4%	26%	0%	33%
Neutral	38%	25%	22%	22%	17%	14%	48%	35%	0%	33%
Comfortable	33%	50%	52%	56%	58%	65%	31%	35%	0%	34%
Very comfortable	5%	0%	13%	5%	22%	15%	0%	4%	100%	0%
How well can you see to do work?										
Very poorly	4%	0%	4%	0%	0%	0%	0%	0%	0%	0%
Poorly	10%	0%	4%	17%	3%	3%	9%	8%	0%	17%
Neutral	29%	50%	5%	17%	11%	15%	26%	23%	0%	50%
Well	43%	50%	57%	61%	58%	62%	52%	50%	16%	33%
Very well	14%	0%	30%	5%	28%	20%	13%	19%	83%	0%
How bright does the area look?										
Very gloomy	10%	0%	0%	5%	0%	5%	4%	0%	0%	0%
Gloomy	19%	25%	4%	17%	5%	3%	9%	19%	0%	50%
Neutral	52%	75%	39%	33%	36%	15%	39%	42%	17%	33%
Bright	19%	0%	44%	28%	53%	59%	44%	27%	17%	17%
Very Bright	0%	0%	13%	17%	6%	18%	4%	12%	17%	17%
Did you see the lights dim?										
Yes		0%		56%		35%		54%		100%
No		100%		44%		65%		46%		0%

Table 5: Aggregated Results: Occupant Acceptance of Load Shedding Ballast System

	Load Shed Off	Load Shed On
# Respondents	113	88
Like lighting in area?		
Dislike very much	6%	1%
Dislike	4%	17%
Neutral	36%	36%
Like	37%	38%
Like very much	17%	8%
How comfortable is lighting?		
Very uncomfortable	7%	1%
Uncomfortable	7%	16%
Neutral	27%	24%
Comfortable	42%	51%
Very comfortable	17%	8%
How well can you see to do work?		
Very poorly	2%	0%
Poorly	6%	8%
Neutral	16%	21%
Well	51%	56%
Very well	25%	15%
How bright does area look?		
Very gloomy	3%	3%
Gloomy	9%	15%
Neutral	40%	30%
Bright	40%	38%
Very Bright	8%	14%
Did you see lights dim?		
Yes		52%
No		48%

Building occupants' perceptions of lighting quality and quantity as measured by the two surveys with the lights at full illuminance (load shed ballast system off) and with the lights at reduced illuminance (load shed ballast system on) are very similar both on an individual demonstration site basis and aggregated, with the exception of Welch Allyn. For Welch Allyn, the load shedding ballasts were located within a space where precision machining to very close tolerances is required. The negative visual capabilities of building occupants caused by the one-third reduction in illuminance was significant in a setting where critical visual tasks are being performed. The illuminance measurements with the lights at full brightness met only minimum recommended illuminance levels for machining areas. The load shedding ballast system probably should not be used where critical visual tasks are required.

OPERATIONAL AGGREGATION OF MULTIPLE SITES

This deliverable was not achieved during the demonstration period. Further software development by EtherMetrics is necessary to aggregate multiple sites. A screen that displays all sites with an on/off function is necessary so that all sites can be controlled at once. An aggregation of the power reduction for all five sites is also needed.

APPLICABILITY OF THE LOAD SHEDDING BALLAST SYSTEM TO PROVIDE SPINNING RESERVE

NYISO allows demand side resources to be used as spinning reserves in the ancillary services electric markets, as long as the resource meets the requirements of NYISO for spinning reserves as set forth in the Ancillary Services Manual, March 2011[11]. These requirements include:

- The location of the DR within the New York Control Area and as to not cause transmission constraints.
- Minimum DR allowed to participate is one megawatt. Aggregation of loads may not be allowed.
- Responding to NYISO commands to reduce load by the prescribed amount within ten minutes of notification.
- Data as to the amount of DR must be transmitted every six seconds.
- It is necessary to conduct a pre-qualification performance test before being allowed to participate in the spinning reserve market.

The amount of demand response associated with a single lighting luminaire is small, 27 watts for a three-lamp T8 fixture. To meet the minimum NYISO participant size with just lighting would require over 37,000 light fixtures with the load shed ballast, or about 5.5 million square feet of floor space. There are few buildings of this size in existence. Therefore, the load shedding ballast system would have to be part of a broader load shedding effort that

[11] New York Independent System Operator. Ancillary Services Manual. March 2011.

included other building loads, or multiple buildings would have to be aggregated to reach the minimum one megawatt requirement.

Testing of the load shedding ballast system at four of the demonstration sites has shown it can respond to a signal input (actuating the on/off button on the EtherMetrics server) via the internet (EtherMetrics server to the demonstration site) to turn on the signal injector and dim the lights within five seconds (measured via a watch) of the signal being initiated. This meets the NYISO requirement of ten minute response. Reporting of load reductions were observed to be occurring every five seconds. This reporting interval meets the six second NYISO requirement. However, the load reporting includes all loads that are connected to the load distribution panel. These loads, including the load shed ballast lighting loads, are variable in nature, turning on and off throughout any given time period. Therefore, the loads being reported every five seconds during the demonstrations were variable, making it impossible to measure an exact reduction in demand. It is believed the accuracy of measuring most DR bid into the spinning reserve markets will be difficult because of the variability of building loads.

The load shedding ballast system, as demonstrated, meets the response and reporting criteria of NYISO. However, the lighting loads included in the system are small and will not meet the minimum size to participate in NYISO spinning reserve programs unless multiple building aggregation is allowed or lighting is included with other building loads to meet minimum size requirements. The ability to accurately measure the amount of DR achieved at a site may be an issue since electrical loads vary. Measurement at the demonstration sites showed varying loads being reported every five seconds. Only an estimate of the amount of load reduced by activating the load shedding ballast system was achievable.

The viability of the load shedding ballast system use in spinning reserve markets is minimized because of the small size of the load reduced, the acceptability of lighting to follow the loading demands of ISO (having the lighting increase or decrease possibly every six seconds to meet ISO load projections) and the variability in reporting reductions in lighting loads due to other loads being on the same data collection system.

Section 5

CUSTOMER ECONOMICS OF THE LOAD SHEDDING BALLAST SYSTEM

Surveys conducted by the LRC regarding a number of lighting products all indicate the primary concern of building owners and designers is to achieve a reasonable payback on the lighting investment[12]. This payback includes operating (energy and maintenance) savings as well as costs for the new lighting system.

Costs to purchase and install a complete load shedding ballast system differ for projects where the lighting system is being upgraded and the load shedding ballast system is added to the project, or where the load shedding ballast system is installed on an existing efficient lighting system. On new construction projects, the costs associated with the addition of the load shedding ballast system are similar to those incurred when adding the system in a situation where a lighting upgrade is already planned. In cases where upgrading the lighting is already planned or for new construction, only the incremental cost of the load shedding ballast system is included. For projects where efficient lighting already exists and the load shed ballasts are replacing existing ballasts, the full cost of the ballasts as well as the labor to install these ballasts are included. Other system elements such as the signal injector, communication gateways and energy management systems are included in upgrades, new construction and replacement scenarios.

There are four potential sources of customer revenue or savings to offset the cost of the load shedding ballast system.

- Reducing the building's monthly peak electric demands to reduce electric billing costs.
- Participation in ICAP programs sponsored by regional transmission and generation organizations/ISOs such as NYISO.
- Providing spinning reserves for demand side ancillary services programs sponsored by ISOs.
- Participation in voluntary demand response programs operated by ISOs or utilities.

To review the cost effectiveness of purchasing a load shedding ballast system and to develop an economic sales tool, the LRC, with assistance from Anthony Abate from NYSERDA, developed a load shed ballast economic calculator. The Excel spreadsheet calculator and documentation for its use are included in Appendix B.

Using the economic load shed calculator, simple payback was calculated for each of the four potential revenue/saving streams discussed above and for both the incremental cost (new construction or retrofitting

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[12] Lighting Research Center, Energy-Efficient Load-Shedding Lighting Technology Final Report. Prepared for the California Energy Commission. January 2005.
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inefficient lighting technologies) and the full cost (retrofitting existing efficient lighting technologies) scenarios. The scenario developed includes the installation of 1,000 load shed ballasts, five signal injectors and communication gateways, and an energy management system (except for the voluntary DR case) for reducing monthly peak demands within New York State. Where available and appropriate, utility or NYSERDA incentives were used to reduce capital costs. Material costs were provided by OSI and EtherMetrics. Labor costs were derived from R.S. Means Electrical Cost Data adjusted for location. Appropriate utility rates [13,14] were used to determine reductions in billing costs. Data from NYISO[15, 16] was used to calculate revenue for participation in ICAP or spinning reserve programs. Table 6 below provides the economic analysis for the above scenarios.

Table 6: Load Shedding Ballast System Economic Analysis

Economics for New Construction or Retrofit of T12 Lighting			
	Incremental Costs	Annual Savings	Simple Payback
Reducing Billing Demand			
ConEdison	$16,563	$7,549	2.2 years
National Grid	$16,563	$5,163	3.2 years
ICAP	$12,909**	$1,578	8.2 years
DSASP	$16,563	$938	17.7 years
Voluntary DR*	$15,463	$270	57.3 years
Economics for Changing a T8 System to Load Shed Ballasts			
	Full Cost	Annual Savings	Simple Payback
Reducing Billing Demand			
ConEdison	$58,800	$7,549	5.8 years
National Grid	$58,800	$5,163	8.0 years
ICAP	$52,712**	$1,578	33.4 years
DSASP	$58,800	$978	60.1 years
Voluntary DR*	$57,700	$270	213.7 years

* assumes 20 hours per year of DR operation

** NYSERDA incentive applied

[13] Consolidated Edison Company of New York. (2011). *Schedule for Electricity Service, P.S.C. No. 9, General-Large Electric Rate, Effective April 1, 2008.* Retrieved from http://www.coned.com/documents/elec/271-281a.pdf

[14] National Grid. (2011). *Rates & Pricing, Large General (SC-3).* Retrieved from http://www.nationalgridus.com/niagaramohawk/business/rates/5_elec_sc3.asp

[15] New York Independent System Operator. *ICAP Auctions, 2010-1999.* Retrieved from http://www.nyiso.com/public/markets_operations/market_data/icap/index.asp

[16] New York Independent System Operator. *Ancillary Sevices.* Retrieved from http://www.nyiso.com/public/markets_operations/market_data/ancillary/index.asp

The economics of installing the load shedding ballast system have to provide a reasonable return on the building owner's investment. The quickest return is through limiting the building's monthly peak electrical demand. Currently, the best economic returns will occur where billing demand charges are high such as New York City and southern California. Even when power is provided by public entities like the New York Power Authority to New York City customers, demand charges may be high.

These economics may change in the future as development of the smart grid includes automatic demand response.

Section 6

DISSEMINATION OF RESULTS

Disseminating information of new technology applications and evaluations is important to the successful transfer of the technology to a commercially viable product. This project included the dissemination of the evaluation results in both written and presentation formats to a wide audience of lighting and non-lighting professionals.

WRITTEN DISSEMINATION

A Field Test DELTA publication has been developed and will be available on the LRC website. This publication presents the technological development of the load shedding ballast system and the evaluation results of the demonstration sites. There are a series of Field Test DELTA publications on emerging technologies of which the load shedding ballast system publication is but one. Field Test DELTA evaluates new energy-efficient lighting technologies to independently verify field performance claims and suggest improvements. A primary goal of the Field Test DELTA program is to facilitate rapid market acceptance of innovative energy-efficient technologies.

A news release based on the Field Test DELTA publication is planned for Fall 2011.

This final report along with the news release and the Field Test DELTA will be posted on the LRC's website. This website is ranked among the highest viewed lighting websites on the internet.

PRESENTATIONS TO LIGHTING PROFESSIONALS AND BUILDING OWNERS AND DESIGNERS

Several presentations regarding the development of the load shedding ballast system and the results of the demonstration projects were completed as part of the deliverables. A list of these presentations is included below. A presentation that was delivered at Siemens' Proven Strategies for Smart, Efficient and Green Facilities is included in Appendix C.

- September 23-24, 2008: Connecticut Light and Power and United Illuminating seminar, Lighting Technologies Update. Attendance: 150 building owners and designers and electrical contractors
- October 17, 2008: AES Latin America Conference on Lighting, Sao Paulo, Brazil. Attendance: 60 utility representatives
- September 23, 2009: Memphis, TN Section Illuminating Engineering Society of North America, Lighting Technology Update. Attendance: 60 building owners and lighting designers
- September 24, 2009: DCO (lighting manufacturer) Tupelo, MS Specifier Seminar. Attendance: 45 building owners and lighting specifiers
- October 9, 2009: Consolidated Edison seminar on lighting. Attendance: 25 utility account managers
- May 24, 2011: Siemens' Proven Strategies for Smart, Efficient and Green Facilities. Attendance: 60 building owners

Section 7

COMMERCIALIZATION

OSI has fully commercialized the load shedding ballast system including the PowerShed® three- and two-lamp, instant start ballasts, the Command Injector® and the Command Coupler®. However, OSRAM Sylvania does not offer a communication module to control the signal injector. They now offer these products to original equipment manufacturers (lighting fixture manufacturers) and through their other distribution channels. Normal lighting distribution channels may be insufficient to enter the demand response market place because of the complexities associated with demand response products and revenue streams. There are entities (curtailment service providers) who have been designated by ISOs to enter into the demand response markets who may be better suited to market the load shedding ballast system to customers.

To explain the benefits and operation of the load shedding ballast system, Peter Morante, LRC, prepared and presented two seminars. The first seminar was for engineering and sales and marketing management at OSI's North American headquarters. The second seminar was a webinar to the OSI national commercial sales force.

The most likely sales success for the load shedding ballast system is where utility demand charges are high, where an incentive is available to write down the capital investment or where energy codes for new construction mandate the use of demand responsive lighting.

Section 8

CONCLUSIONS

Base on the results from the demonstration and evaluation of the load shedding ballast system, the following conclusions are made.

- A cost effective (for new construction and replacement of inefficient lighting systems) load shedding ballast system was developed and is commercialized including a high efficiency load shed ballast, a power line carrier signaling device and a communication gateway.
- The power line carrier signaling method to each ballast proved to be effective with no interference to other electronic devices.
- Equipment installation of the load shed ballasts were observed to take the same amount of time as any other ballast installation. The installation complexity of the signal injector is dependent on the installation site specifics.
- The wiring device within the signal injector where the incoming power is terminated should be changed to accommodate larger wire sizes.
- The operation of the load shedding ballast system through the internet, where either a building management system is not present or not feasible, is straight forward and easy. Once the secure EtherMetrics server is accessed, one click of the mouse turns the system on or off. The use of outbound only communications between the communication gateway and the server allowed for passage through demonstration site firewalls. The EtherMetrics DataCube and server are inexpensive alternatives for a BMS.
- The measured load reduction achieved by the load shedding ballast system was close to the anticipated load reductions.
- Illuminance level reductions were also near anticipated levels when the load shedding system was in operation.
- Occupant acceptance of the load shedding ballast system in terms of perceptions of light quality and quantity were satisfactory to conclude the load shedding ballast system will not adversely affect occupants productivity in most instances.
- Where critical visual tasks are performed, the load shedding ballast system should not be installed.
- The fastest return on the customer's investment in the load shedding ballast system is provided by reducing the building's peak monthly electrical billing demand.

Appendix A: Building Occupants Sample Survey Instruments

First Survey: Load Shed not in Operation (full illuminance)
??? Company and the Lighting Research Center, a part of Rensselaer Polytechnic Institute, are conducting an experiment to determine if the lighting system can be used to reduce peak electric demands. We need your assistance in analyzing the current lighting system.

Please consider the lighting at your work area and answer the following questions by circling the appropriate answer. The survey is completely voluntary, confidential and anonymous. Then, please return this questionnaire to the Lighting Research Center Rep.

Background:

1. In a day, how many hours do you usually spend at your work station or cubicle?
   less than 2, 2-4, 4-6, 6-8, or more than 8
2. While you are at your work station or cubicle, how do you spend most of your time?
   1: operating machinery, 2: computer work, 3: other ( )
3. Please describe your job briefly, i.e., machinist, supervisor, technician.
   ( )
4. Do you have task lights at your work station? A task light is "extra" lighting like that found on a desk top or attached to a machine
   1: yes, 2: no

   If yes,

- How many task lights do you have? ( )
- What types of light bulbs are they? Fluorescent lamps, incandescent lamps, halogen lamps, or other ( )
- What is the total wattage of the tasks lighting? ( ); unknown
- How many hours do you usually use the task lights per day? ( )

General questions on lighting:

1. How do you like the lighting in your area?
   -2: dislike very much, -1: dislike, 0: neutral, 1: like, 2: like very much
2. How comfortable is the lighting in this area of the building?
   -2: very uncomfortable, -1: uncomfortable, 0: neutral, 1: comfortable, 2: very comfortable
3. How well can you see to do your work at your machine or cubicle?
   -2: very poorly, -1: poorly, 0: neutral, 1: well, 2: very well
4. How bright does the area look?
   -2: very gloomy, -1: gloomy, 0: neutral, 1: bright, 2: very bright
5. How bright is the lighting at your work station for the tasks you perform?
   -2: too dim, -1: dim, 0: about right, 1: bright, 2: too bright
6. How does the lighting in your part of the building compare with other parts of the building?
   -2: much worse, -1: worse, 0: about the same, 1: better, 2: much better

If you have any questions regarding this survey, please contact Peter Morante, Lighting Research Center at (518) 687-7100 or via email moranp@rpi.edu.

Second Survey: Load Shed Operational (Lights Dimmed)
??? Company and the Lighting Research Center, a part of Rensselaer Polytechnic Institute, are conducting an experiment to determine if the lighting system can be used to reduce peak electric demands. We need your assistance in analyzing the current lighting system.

Please consider the lighting at your work area and answer the following questions by circling the appropriate answer. The survey is completely voluntary, confidential and anonymous. Then, please return this questionnaire to the representatives from the Lighting Research Center.

Background:

1. In a day, how many hours do you usually spend at your work station or your cubicle?
less than 2, 2-4, 4-6, 6-8, or more than 8

2. While you are at your work station or cubicle, how do you spend most of your time?
1: machine work, 2: computer work, 3: other ( )

3. Please describe your job briefly, i.e., machinist, supervisor, technician.
( )

General questions on lighting:

4. How do you like the lighting in your area?
-2: dislike very much, -1: dislike, 0: neutral, 1: like, 2: like very much

5.How comfortable is the lighting in this area of the shop?
-2: very uncomfortable, -1: uncomfortable, 0: neutral, 1: comfortable, 2: very comfortable

6.How well can you see to do your work at your work station or cubicle?
-2: very poorly, -1: poorly, 0: neutral, 1: well, 2: very well

7. How bright does the area look?
   -2: very gloomy, -1: gloomy, 0: neutral, 1: bright, 2: very bright

8. How bright is the lighting at your work station for the tasks you perform?
   -2: too dim, -1: dim, 0: about right, 1: bright, 2: too bright

9. A short time ago we dimmed the lights to reduce peak electrical usage. Did you notice the lights being dimmed? 1: Yes 2: No

If you have any questions regarding this survey, please contact Peter Morante, Lighting Research Center at (518) 687-7100 or via email moranp@rpi.edu.

Appendix B: Load Shedding Ballast System Economic Calculator

Remodel/Fixture Replacement						
INPUT VARIABLES			**CALCULATED VARIABLES**			
Existing Lighting Design Variables		units			units	
number of fixtures being replaced	200		Total lighting wattage - existing design	30.2	kW	
number of bulbs per fixture	4	blb/fixt	Total lighting annual energy use - exisitng design	75,500	kWh	
labeled wattage per bulb	34	watt/blb	Existing Design - Demand & energy cost per year	$ 15,877	/year	
ballast factor (Mag = 1.0, Elect = 0.88)	1		Wattage for lamps - esisting fixture	136	watts/fixture	
Operating wattage per lamp	34	watts/lamp	Existing system watts per fixture (lamps + ballasts)	151	watts/fixture	
ballast wattage per fixture (mag = 15W, 1st gen elec = 5W)	15	watts				
Annual op hours of existing fixtures	2500	hr/year				
New Lighting Design Variables (non-retrofit)						
total number of new fixtures in design	200		Total lighting wattage - new design(load-shed & non-load-shed)	16.4	kW	
ASSUME: Load-shed and non-load shed fixtures are same wattage			Total load shed lighting wattage - new design	16.4	kW	
number of new load shed ballast/fixtures in design	200		Total lighting annual energy use - new design	41,000	kWh	
ballasts per new fixture	1	assumed	New Design - Demand & energy cost per year, no load shedding	$8,622		
bulbs per ballast	3	blb/blst	Wattage for lamps - new fixtures	80	watts/fixture	
operating wattage per bulb (not nominal wattage)	26.5	watts	New system watts per fixture (lamps + ballast)	82	watts/fixture	
ballast wattage per fixture	2.5	watts	DR wattage per ballast/fixture	0.02706	kW	
Annual op hours of new fixtures	2500	hr/year	Total load shed possible	5.412	kW	
Demand response power reduction as % of total fixture wattage	33%					
New Fixture Costs	Assume replacement of fixtures - not retrofit, does not include load shed costs					
Cost per new fixture including standard ballast, do not include load shed incremental cost	$100.00	per fixture				
Per lamp cost	$1.50					
Labor to install new fixture	$110.00					
Total cost per fixture with lamps & labor: exclude additional load shed cost	$214.50		Total cost to retrofit with new fixtures T12s to T8	$42,900		
Load Shed Costs	Assume replacement of fixtures - not retrofit					
number of required signal injectors in load shed design	1					
Load-shed ballast marginal cost	$9	per ballast	Total LSB system cost	$4,337	includes any EMS/other costs	
Signal injector cost	$900	per injector				
Signal injector install cost (labor)	$308	per injector	LSB system cost per ballast	$21.69	$/ballast	
If needed, EMS Cost and Other Costs	$1,329	per project				
examples of other costs: communication wiring, relays, power supplies, etc.)			Cost per load-shed kW	$801.37	$/kW	
In lieu of EMS installation, customer may elect to subscribe to an outside EMS seervice for a monthly fee	$0.00	per month	Annual outside EMS fee	$0.00		
Energy & Demand Chaarges						
Flat energy charge	$0.08	/kWh	Existing Design - Demand & Energy cost per year, No Load Shedding	$ 15,877	/year	
Summer (4 months) Demand Charge	$47.33	kW-mo	New Design - Demand & Energy cost per year, No Load Shed	$8,622	/year	
Winter Demand Charge	$17.05	kW-mo	Efficiency cost savings per year - demand & energy	$ 7,255		
			Efficiency savings per fixture per year	$ 36.27		
			% savings	45.70%		
			Load Shed Demand Reduction	5.412	kW	Assume same all 12 months
			Load Shed Demand Cost Savings (reduction in peak billing demand)	$ 1,763	/year	

Revenues from NYISO / Aggregator				
Est. I-cap Day-ahead kw- mo price	$6 $/kW-mo	Annual facility ICAP revenue	$316	
Aggregator % fee	10%			
Load Shed Economic Analysis				
		Load Shed Incremental Cost	$4,337	
		Less NYSERDA DR Incentive	$0	
		Net Load Shed Cost	$4,337	
		Annual Load Shed Customer Billing Reduction Savings	$1,763	/year
		Annual facility ICAP Revenue	$316	
		Load Shed Simple Payback based on Higher Customer Billing Reduction or ICAP Revenue	2.46	years
Efficiency Improvements Economic Analysis (new fixtures, does not include load shed costs)				
		Cost for new installed fixtures, no load shed costs	$42,900	
		Less NYSERDA EE Incentive	$0	
		Net new fixture cost	$42,900	
		Efficiency savings per year	$ 7,255	/year
		Simple Payback for Efficiency Improvements Only	5.91	years

Documentation for
Load Shed Ballast
Economic Calculator

March 11, 2010

Purpose: This economic calculator will assist customers, energy service companies and load shed marketers in determining where the load shed ballast system makes economic sense for three potential installation scenarios.

- Replacing existing lighting fixtures that have T12 lamps and magnetic ballasts with new lighting fixtures that have T8 lamps and the load shed ballast.
- Retrofitting existing lighting fixtures that have T12 lamps and magnetic ballasts with T8 lamps and the load shed ballast without replacing existing fixtures.
- Retrofitting existing lighting fixtures that have T8 lamps and electronic ballasts with the load shed ballast.

It will also assist in determining the economics for improving the energy efficiency of lighting systems.

General User Interface: First, the user must decide which of the three installation scenarios applies to the situation they are analyzing. Each scenario is a separate tab within the economic calculator.

T12 Replacement Tab: If the user intends to replace existing light fixtures that contain T12 lamps and magnetic ballasts with new fixtures containing T8 lamps and load shed ballasts, they would use this tab. This tab allows the user to determine the demand and energy cost of the existing lighting system, the demand and energy cost of the replacement system to include any redesign of the lighting which may use less fixtures and the additional cost savings that may occur because of the use of the load shed ballasts and costs and economics for the new fixtures. The load shed ballast costs are based on the incremental cost of the load shed ballast over that of instant start T8 electronic ballasts because the ballast must be replaced anyways.

T12 Retro Tab: If the user intends to just retrofit existing T12 and magnetic light fixtures with T8 lamps and load shed ballasts, they would use this tab. This tab allows the user to determine the demand and energy cost of the existing lighting system, the demand and energy cost of the retrofitted system and the additional cost savings associated with just the load shedding ballasts. Retrofit costs and savings are included also. The load shed ballast costs are based on the incremental cost of the load shed ballast over that of instant start T8 electronic ballasts because the ballast must be replaced anyways to gain energy efficiency savings.

T8 Retrofit Tab: If the current lighting system utilizes T8 lamps and electronic ballasts, the user would use this tab to determine the economic viability of the load shed ballast system. This tab allows the user to determine the demand and energy cost of the existing lighting system, the demand and energy cost of the retrofitted system and the additional cost savings associated with just the load shedding ballasts. The retrofitted system may use less energy than the existing T8 system because the load shed ballast is a NEMA Premium high efficiency ballast or because lower wattage T8 lamps are used. The load shed ballast costs are based on the full installed cost of the load shed ballast since a T8 ballast is already in use.

Input Variables: All three scenarios use the same inputs with the exception of the T8 Retrofit Tab; Load Shed Costs. For the T8 Retrofit Tab the full cost of the load shed ballast should be used. The other two scenarios should use the incremental cost of the load shed ballast.

Existing Lighting Design Variables: These inputs need to reflect the lighting system that is being replaced. The next entries define the energy use of these fixtures.

- Number of fixtures being replaced
- Number of lamps/bulbs per fixture
- Labeled wattage of each lamp/bulb
- Ballast factor of the existing ballast (usually 1.0 for magnetic ballasts and 0.88 for electronic ballasts)
- Wattage of the ballast(s) per fixture

- Annual operating hours of the lighting system.

- New Lighting Design Variables/Lighting Retrofit Variables: These inputs need to reflect the lighting system that is being considered as a replacement. The next entries define the energy use of these new fixtures.
- Number of lighting fixtures in the new design. If a redesign of the lighting system is being considered, it may use fewer fixtures than the existing lighting system.
- Number of new lighting fixtures that will have load shed ballasts installed. Not all of the new fixtures may have load shed ballasts.
- Number of lamps/bulbs per ballast/fixture
- Operating wattage of each lamp/bulb (operating wattage, not rated wattage)
- Wattage of the ballast per fixture
- Annual operating hours of the new lighting system
- Percent of fixture (lamps + ballast) wattage that will be reduced when the load shed system is on.

New Fixture Costs or Retrofit Costs: If new fixtures are to be used, enter costs for the fixture including standard ballast costs. Enter separately cost per lamp and labor to install the new fixture. The price should not include the incremental cost of the load shed ballasts.

If retrofitting existing fixtures with new lamps and ballasts, enter costs for the new instant start ballast. Enter separately costs for new lamps and for labor to change out ballast and lamps. The price should not include the incremental cost of the load shed ballasts.

Load Shed Costs: The T8 Retrofit scenario will use full costs for the load shed ballasts rather than marginal/incremental costs as is used with replacing/retrofitting T12 lighting systems.
- Number of required load shed signal injectors for the entire project. One signal injector is needed at each lighting distribution electrical panel that has load shed ballasts installed on it.
- Load shed ballast marginal cost. Since the fixture and/or the ballast is already being replaced to convert the existing lighting system to T8s, only the incremental/marginal cost of the load shed ballast should be considered. This is the difference between the cost of the load shed ballast and an instant start electronic ballast.
- Load shed ballast total installed cost. This is only used in the T8 Retrofit scenario. Because the existing lighting system already uses T8s, the full cost to purchase the load shed ballast and install it into existing fixtures must be included.
- Signal injector cost. Enter the cost to purchase a single signal injector.
- Signal injector install cost. This is the labor cost to install a signal injector.
- EMS cost and other costs. If the customer is going to try to reduce peak billing demands and the building does not have an energy management system, one may be needed. There also may be other costs to install the load shed ballast system that are unknown by the developers of this calculator. This data entry will allow the user to include those costs such as communication wiring, relays, power supplies, etc. If the customer is only going to participate in the NYISO SCR program, there is no need for an EMS system. The user should enter $0 for this input.
- EMS subscription monthly fees: An alternative to installing a dedicated EMS is to subscribe to a EMS service provided by others. Service providers usually charge a monthly fee for this service.

- Energy and Demand Charges: The user should use the actual electric rate used for billing the facility. Today’s electric rates have multiple parts, transmission charges, distribution charges, system benefit charges, renewable energy charges, generation services charges, etc. These charges are usually expressed in either demand charge (dollars per kW) or energy charge (dollars per kWh) or both. The user can add up all demand charges and energy charges for all the parts of the rate to arrive at a total energy charge and total demand charge.

- Flat energy charge. This is the total per kWh charge for all parts of the electric rate. Sometimes there will be a summer and other months difference in energy charges. If this is true, determine the annual average energy charge per kWh and enter this amount here.

- Summer (4 months) demand charge. If the electric rate has a different summer demand charge than it does for other months, it should be entered here. If the demand charge is the same throughout the year, enter the monthly demand charge here and again in the winter demand charge data entry.
- Winter demand charge. Enter the winter demand charge here. If there is no difference between winter and summer demand charges, enter the monthly demand charge here and in the summer demand charge box.
- Note: The calculator uses four months of summer demand charges. This is the most common period for summer charges found throughout the U.S. However, there are some electric rates with different summer charge periods. If the user encounters a summer period different than four months, he/she must make changes in the calculated demand and energy cost value formulas found on the right side of the calculator spreadsheets (existing design demand and energy cost per year; new design- demand and energy cost per year, no load shedding; load shed demand cost savings)

- NYSERDA Energy Efficiency Incentive (kWh): NYSERDA in New York and other entities in other states may offer monetary incentives to customers to convert their existing inefficient lighting systems to more efficient lighting systems. These incentives are usually expressed in dollars per fixture converted or dollars per kWh saved. If expressed in dollars per kWh saved, the user must convert this amount to dollars per fixture to be entered into the calculator.

- Yes/No >50% of facility kWh purchased from a system benefit charge (SBC) utility. Since NYSERDA funding for incentives comes from the SBC, the facility must be paying into the SBC. If the customer is buying power from a municipal utility, NYPA or other entity and does not pay into the SBC, the customer is not eligible for NYSERDA incentives. In this case the user would enter “2” “no” in the calculator. If the facility is located in another state and incentives are available enter “1” “yes”. If no incentive is available, enter “2” “no”.
- Yes/No in ConEd territory. NYSERDA and possibly Consolidated Edison offer additional incentives if the facility is located in its service area. Entering “1” “yes” for this entry will allow the calculator to use the higher incentive. If the facility is located in another part of New York or another state, enter “2” “no”.
- NYSERDA ConEd incentive. Enter the per fixture incentive that NYSERDA has determined if the facility is located in New York City. If the facility is located someplace else in New York or another state, enter zero.
- NYSERDA Upstate incentive. Enter the per fixture incentive that NYSERDA has determined for other than NYC locations. If there is an incentive available from other states it should be entered here.

- NYSERDA Demand Response Incentive: NYSERDA offers a monetary incentive for registered demand response (DR) loads to offset the cost of installing these loads. The load must be registered to participate in the New York Independent System Operators (NYISO), SCR program. A demand response incentive may be offered in other states.

- Yes/No, Is the DR load registered as NYISO SCR? Enter “1” if registered or “2” if not registered. If the DR load is not registered, no incentive is available and the calculator will not include any incentives in its cost estimates.
- Yes/No, Is the DR load in ConEd service area? Enter “1” if yes or “2” if no. NYSERDA pays a higher incentive if the DR is located in ConEdison’s service area. The calculator will use the higher ConEdison incentive. If the DR is located in another state location, the calculator will use a lower incentive.
- Percent of Load Shed Registered: Since there is a possibility that not all lighting fixtures containing load shed ballasts will be on when demand response is required, the customer will more than likely register something less than 100% of the load shed ballast curtailment. This is the percentage that should be entered here.
- NYSERDA ICAP ConEd: Enter the NYSERDA incentive for DR for curtailable loads within ConEdison service area.
- NYSERDA ICAP Upstate: Enter the NYSERDA incentive for registered DR for curtailable loads for the remainder of the state.
- NYSERDA Load Shed Bonus: From time to time NYSERDA has offered a bonus incentive for the installation of demand response. If a bonus incentive exists, this is where it should be entered.

Revenues from NYISO/Aggregator: Participation in NYISO ICAP programs is usually through demand response aggregators. NYISO sets the value of ICAP resources on a day ahead basis based on the value of a kW-month. These values are posted on the NYISO website.

- Estimate Day-ahead kW-mo Price: The calculator user must determine the approximate value of the ICAP resource based on a kW-mo. This value should be the monthly average calculated over a twelve month period for the zone where the load shed is located.
- Aggregator % fee: The demand response aggregator will take a portion of the NYISO payments as an administrative fee for operating the program for the customer. The user needs to enter this fee as a percentage of the payment.

Calculated Outputs: Based on the inputs, the calculator will determine demand and energy use and costs of the existing lighting system and proposed changes. It will also calculate the cost of installing the energy efficiency improvements and the load shed ballast system, any incentive available to offset these costs and potential cost reductions from controlling the building's peak demand or participation in the NYISO ICAP program. The economic analysis presents a simple payback in years to pay off the energy efficiency improvement and the load shed investment less any incentives.

Existing Lighting Design: Demand, energy and electric costs are calculated based on the user's inputs.

- Total lighting wattage – Existing design: The calculator uses the number of fixtures, lamps per fixture, wattage per lamp and wattage of the ballast to determine the total wattage of the existing lighting system. To convert the wattage into kilowatts, the wattage is divided by 1000.
- Total lighting annual energy use - existing design is calculated by multiplying the total lighting wattage by the hours of operation.
- Existing Design, Demand and energy cost per year: The calculator uses the kilowatts of the lighting system times the hours of operation times the cost per kWh to determine the energy portion of the costs. To this is added the monthly demand charges which is the kW of the existing light system times the demand charges for both summer and winter months.
- Existing system wattage per fixture is the ballast wattage plus the operating wattage of all lamps.

New Lighting Design/Retrofit: This section includes the calculations of the wattage for the new or retrofitted lighting design, energy use, the demand and energy costs of that design and possible load shedding.

- Total Lighting Wattage – New or Retrofit Design: The calculator uses the number of new or retrofitted fixtures, lamps per fixture, wattage per lamp and wattage of the ballast to determine the total wattage of the new/retrofitted lighting system. To convert the wattage into kilowatts, the wattage is divided by 1000.
- Total load shed lighting wattage: The calculator uses the number of new or retrofitted fixtures that have the load shed ballast installed, lamps per fixture, wattage per lamp and wattage of the ballast to determine the total load shed wattage of the new/retrofitted lighting system. To convert the wattage in to kilowatts, the wattage is divided by 1000.
- New Design – demand and energy cost per year, no load shedding: This is the cost of electricity to operate the new or retrofitted lighting system without the load shed system in operation. It is calculated by multiplying the wattage of the new/retrofitted system by the annual operating hours and by the cost per kWh. To this is added the monthly demand charges for the lighting system.
- DR wattage per ballast/fixture: The load shed ballast will reduce the total fixture wattage by the demand response power reduction expressed as a percentage of total fixture wattage. The calculator uses the total lamp wattage plus the ballast wattage and reduces these values by the demand response percentage to determine the wattage per fixture that is demand response.
- Total load shed possible: The total load shed possible is the demand response per fixture times the number of fixtures that have the load shed ballast installed.

New Fixture or Retrofit Costs: The choice of new fixture or retrofit costs is based on which scenario has been chosen by the user. The total cost to retrofit with new fixtures is the cost per fixture including an instant start ballast plus lamp costs plus labor to install the fixture times the number of new fixtures installed. It includes both material and labor but not the incremental cost of the load shed system. The total cost to retrofit just lamps and ballasts into existing fixtures is the cost of ballast and lamps plus labor per fixture times the number of fixtures that are retrofitted. It includes both material and labor but not the incremental cost of the load shed system.

Load Shed Costs: These are either the marginal/incremental costs or the full costs for installation of the load shed ballast system including any additional costs for energy management systems needed to reduce the monthly peak electric billing demands.

- Total LSB system cost: For the fixture replacement and T12 retrofit scenarios, the total cost includes the marginal/incremental cost of the load shed ballast over a standard instant start ballast plus the installed (material and labor) cost of all necessary signal injectors plus the installation of an energy management system and other needed equipment if required. For the T8 retrofit scenario, the calculator uses the full installed (material and labor) cost of the load shed ballast.
- LSB system cost per ballast: This is simply the total load shed ballast system cost divided by the number of load shed ballasts installed.
- Cost per load-shed kW installed: To determine the cost per kW of demand response, the calculator divides the total load shed ballast system cost by the total possible demand reduction produced by the load shed ballasts.
- Annual outside EMS fee: If the customer elects to use an EMS provider rather than install a dedicated EMS, they will pay a subscription fee for this service. The annual outside EMS fee is the monthly fee times 12 months.

- Energy and Demand Charges: The outputs in this section reveal the costs to operate the existing and replacement lighting systems and any cost savings from the load shed ballast system produced by reducing the facility's monthly peak billing demands.
- Existing Design and New Design Demand and Energy costs per year: These costs are repeats of the demand and energy costs calculated earlier in the process.
- Efficiency cost savings per year: This is the difference between the cost to operate the existing lighting system and the replacement lighting system without considering any demand response savings caused by the load shed ballast system. i.e. the demand and energy cost savings from changing a T12 lighting system to a T8 lighting system.
- Efficiency savings per fixture per year: This is the efficiency savings per year divided by the number of fixtures converted to the new technology.
- % savings is the percent of cost savings compared to the existing system's demand and energy costs.
- Load shed demand cost savings: This calculation determines the annual billing demand cost savings attributable to the operation of the load shed ballast system. It is calculated using the summer and winter demand charges times the load shed demand reduction. It assumes the demand reduction will be the same each month.
- Demand charge savings per load shed fixture per year: This is the load shed demand cost savings divided by the number of load shed ballasts installed.

NYSERDA Energy Efficiency Incentive: This section calculates the incentive, if any, that is payable to the customer if he/she improves the efficiency of the existing lighting system by installing electronic ballasts and higher efficiency lamps like T8s. It does not include incentives that might be available for implementing demand response actions.

NYSERDA Demand Response Incentive:

- Total lighting DR registered SCR: Since there is a possibility that not all the lighting will be on when the independent system operator calls for curtailment, the total load shed demand reduction is multiplied by the percent of load registered.
- Total NYSERDA DR incentive: This is the amount that NYSERDA will pay the customer for registering the load shedding with NYISO. It is based on the customer location and the amount per kW.

- Revenue from NYISO/Aggregator:
- Annual facility ICAP revenue: If the customer elects to participate in the NYISO ICAP program, they will get paid based on the registered kW, the average ICAP day-ahead kW-month pricing less any fees the aggregator may collect for administrating participation.

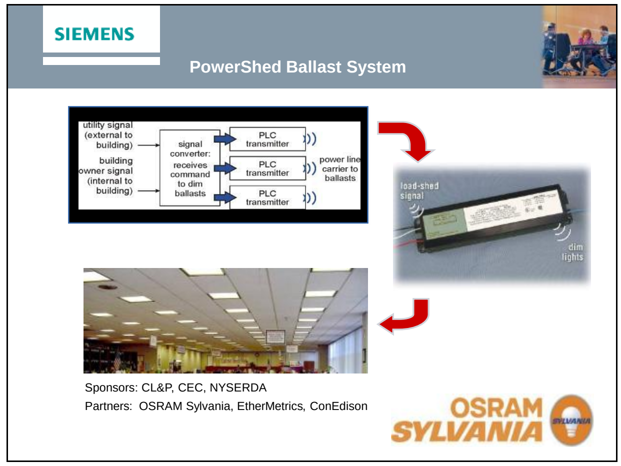
- Load Shed Economic Analysis: This section is designed to provide the user with a simple payback on the customer's investment in the load shed ballast system by examining both the revenue streams of reducing peak monthly facility electric billing demands and ICAP payments from NYISO.

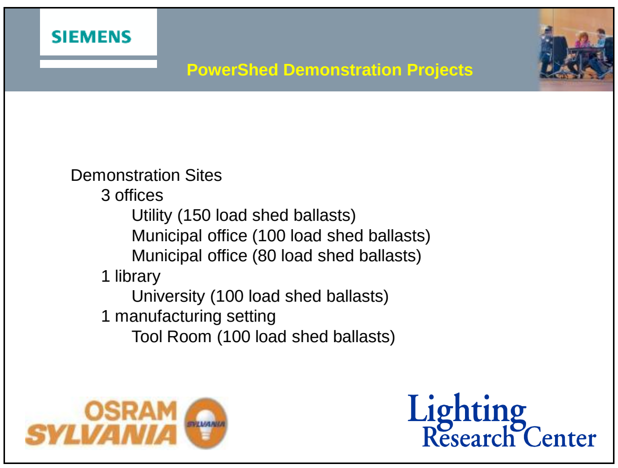
- Load Shed Incremental or Installed Cost: This is a restatement of the cost to install the load shed ballast system. If the existing lighting system is T12 and is being replaced with new light fixtures or the T12 system is being retrofitted with T8s, then only the incremental cost above that of installing instant start ballasts rather than the load shed ballast system is included. If the existing system already utilizes T8s, then the full installed cost of the load shed ballast is included.
- Net Load Shed Cost: If a DR incentive is available, it is subtracted from the total cost of the load shed ballast system to arrive at a net cost.
- Annual Load Shed Customer Billing Reduction Savings and Annual Facility ICAP Revenue: These restate the two possible revenue streams that are available to the customer. The customer can elect to either participate in the ICAP program or reduce their monthly billing demands. They cannot participate in both. For the billing reduction savings, the annual subscription fee for the outside EMS, if used, is subtracted from the savings.
- Simple Payback: The calculator selects the higher revenue stream (either reducing monthly bills or ICAP) and divides the net load shed ballast system cost by the higher revenue stream. The results are presented in years to pay back the load shed ballast system investment.

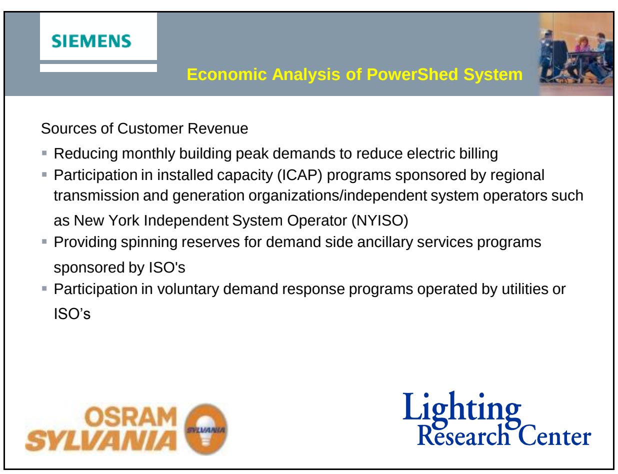
Efficiency Improvements Economic Analysis: This output shows the economic analysis for either installing new fixtures or retrofitting existing fixtures with new, more efficient lamps and ballasts.

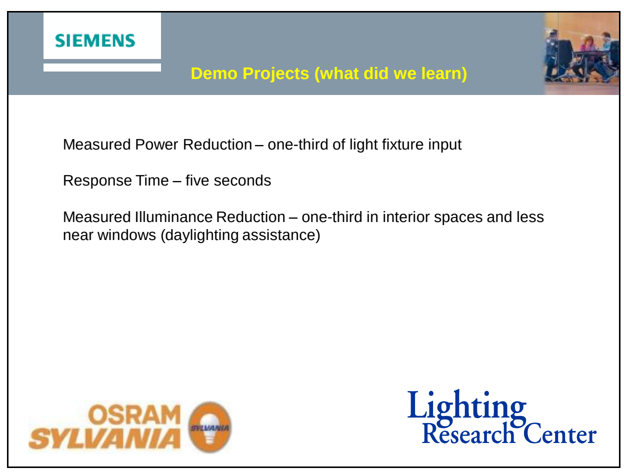
- Cost for new fixtures/retrofit: This is the total cost to either replace existing fixtures with new ones or the total cost to retrofit existing fixtures with new lamps and ballasts. Included in the cost is material and labor but not the incremental costs of the load shed ballast system. It is derived by multiplying the cost per new fixture or cost to retrofit a fixture times the number of fixtures replaced or retrofitted.
- Net new fixture/retrofit cost: This amount subtracts out any NYSERDA energy efficiency incentive that is available from the total cost for new fixtures or retrofitting existing fixtures.
- Simple payback for efficiency improvements only: The calculator divides the net cost to make the efficiency improvement by the annual efficiency savings. This figure does not include any costs or savings attributable to load shedding.

Appendix C: Powerpoint Presentation to Siemens' Proven Strategies for Smart, Efficient and Green Facilities Seminar



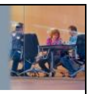






SIEMENS

Demo Projects (what did we learn)

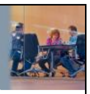


Occupant acceptability of reducing light level (other manufacturing facility)

- Surveys of building occupants with system off and on (over 100 surveys).
- Did you see lights dim?
  - Yes – 49%   No – 51%
- How comfortable is lighting?
  - Load Shed Off – comfortable/very comfortable **78%**
  - Load Shed On - comfortable/very comfortable **72%**
- How bright does area look?
  - Load Shed Off – about right/bright **65%**
  - Load Shed On – about right/bright **70%**
- How well can you see to perform your work tasks?
  - Load Shed Off – see well/very well **78%**
  - Load Shed On – see well/very well **77%**

SIEMENS

Economic Analysis of PowerShed System



Economics for New Construction or Replacement of T12 Lighting			
	Incremental Cost	Annual Savings	Simple Payback
Reducing Billing Demand			
ConEdison	$14,340	$6,896	2.1 Years
National Grid	$14,340	$5,183	2.8 Years
ICAP	$10,687	$2,315	4.4 Years
DSASP	$14,340	$938	14.8 Years
Voluntary DR*	$14,340	$270	53.1 Years
Economics for Changing a T8 System to Load Shed			
	Full Cost	Annual Savings	Simple Payback
Reducing Billing Demand			
ConEdison	$56,000	$6,896	6.0 Years
National Grid	$56,000	$5,183	10.8 Years
ICAP	$52,347	$2,315	22.6 Years
DSASP	$56,000	$938	59.7 Years
Voluntary DR*	$56,000	$270	207.4 Years