FIELD TEST DELTA

Demonstration and Evaluation of Lighting Technologies and Applications

DEMAND-RESPONSE, LOAD-SHEDDING BALLAST SYSTEM

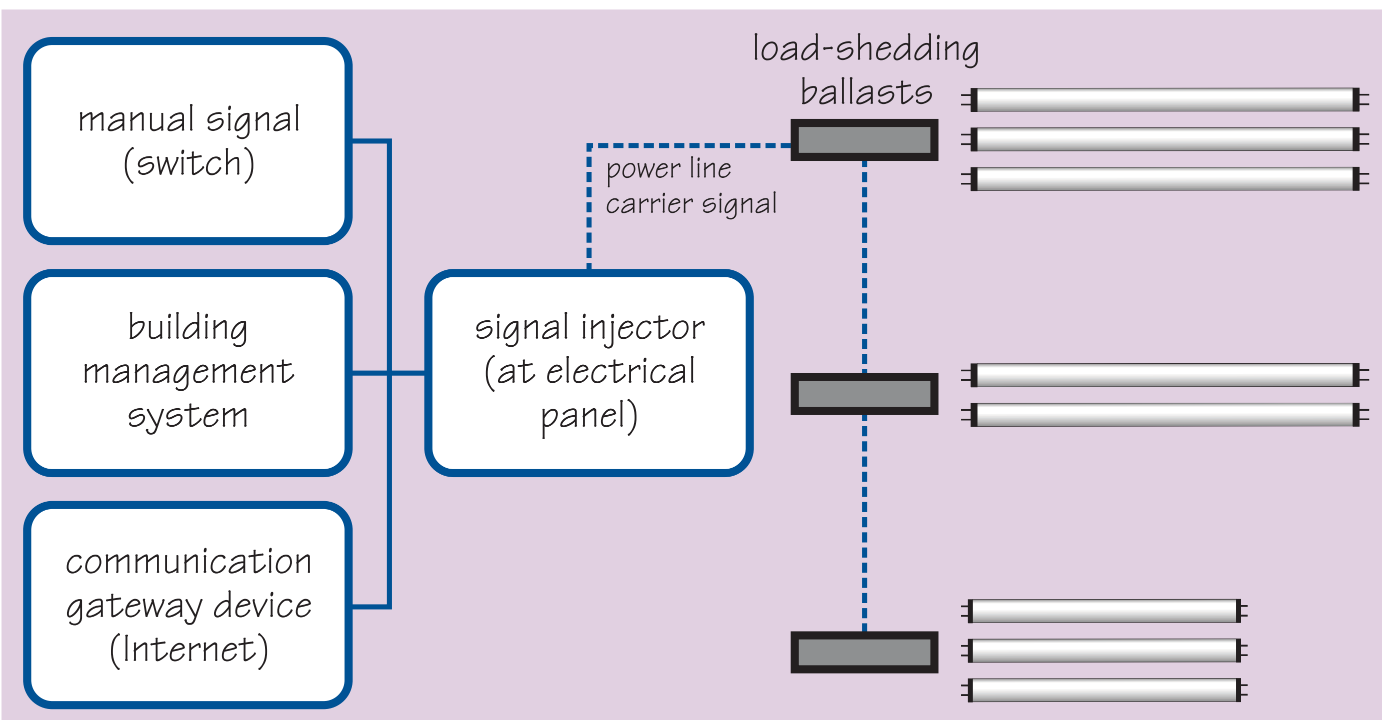
Project Profile

Demand-response building systems are an important component of electricity load management programs. Commercial building owners benefit from demand-response programs by reducing both electricity costs and the possibility of complete shutdown due to blackouts during times of utility peak electric loads. In commercial buildings, lighting is a major electrical load, yet it can be dimmed during times of peak demand without reducing work productivity. Temporary reduction of lighting loads is repeatable, predictable and immediate, making lighting an excellent candidate for any demand-response/load management (DR) program.

Until recently, the inclusion of lighting into any DR strategy has involved turning off banks of lights manually or through a building management system with complicated distribution and/or control wiring. With its partners, OSRAM Sylvania, Encore Electronics, EtherMetrics, and Consolidated Edison, the Lighting Research Center (LRC) developed, demonstrated and evaluated a cost-effective, load-shedding ballast system to command the lighting to dim at times of peak electric demand, without installing additional wiring.

Field Test Objectives

- Develop and test a load-shedding ballast system for fluorescent lighting 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 a demand-response program
- Provide demonstration sites with the ability to control their monthly peak electric billing demands
- Confirm load reduction amounts
- Confirm response times
- Evaluate building occupants' satisfaction
- Assist in the commercialization of a load-shedding ballast system



Load-shedding system diagram. The system accomodates 2- and 3-lamp configurations of T8 linear fluorescent lamps.

Overview of the Load-Shedding Ballast System

The system has three components: addressable ballasts, a signaling mechanism to command the ballasts, and a communication system to control the signaling mechanism.

The load-shedding ballast, the heart of the system, was developed and commercialized by OSRAM Sylvania with assistance from the LRC. The load-shedding ballast combines a NEMA Premium[1] instant-start ballast with bi-level dimming and a built-in power line carrier signal receiver for automated dimming response. Appearance, installation and wiring are identical to standard, instant-start electronic ballasts. The load-shedding ballast replaces a conventional ballast in each luminaire. Operation is limited to T8 linear fluorescent lamps.

A signal injector, also developed and commercialized by OSRAM Sylvania with assistance from the LRC, communicates with all the load-shedding ballasts in the system. The signal injector is placed at electric distribution panels to inject a power line carrier signal, which travels over existing wiring to each load-shedding ballast.

Several options are available to initiate the system's operation: the system can be turned on manually, can be tied into a building management system, or can be connected through a local area network to an Internet server external to the building. For this demonstration, four of the five sites were connected to the Internet with a simple, low cost, communication gateway device developed by EtherMetrics. The EtherMetrics data server aggregated the four demonstration sites and turned all load-shedding systems on within ten seconds of a signal being generated. Load data from the sites were reported back every five seconds.

The fifth demonstration site controlled the load-shedding ballast system manually using its building management system.

When the load-shedding ballast system is engaged, power is reduced by one-third to the T8 lamps. As a result, illuminance is also reduced by approximately one-third. This one-third reduction was chosen based on previous LRC research showing no decrement to lamp life and acceptance from building occupants for periods of up to two hours.[2,3]

[1] The National Electrical Manufacturers Association (NEMA) has established a program to label and encourage the use of high efficiency ballasts that operate T8 linear fluorescent lamps.

[2] Garza, F. 2003. A study of cathode fall voltage and lamp life of T8 instant-start fluorescent lamp systems under low lamp current conditions. (Troy, N.Y., Lighting Research Center).

[3] Neches J. 2003. Detectability and acceptability of illuminance reduction for load shedding. (Troy, N.Y., Lighting Research Center).

Demonstration Sites

In 2010-2011, the load-shedding ballast system was installed and operated at five sites in New York State. Four sites were located in New York City, and the fifth was located in Skaneateles Falls in central upstate New York. Field test parameters are summarized in the table below.

Demonstration Site	New York City, NY				Skaneateles Falls, NY
	City of New York, 15th Floor Offices	City of New York, 19th Floor Offices	Columbia University, Offices	Yeshiva University, Library	Welch Allyn, Industrial Machining Area
Before					
Ballast quantity	100	80	100	100	100
Lamp type	4' (32W)	4'(32W)	4'(32W)	3' (25W), 4' (32W)	4' (34W)
	T8	T8	T8	T8	T12
Lamps per luminaire	3	3	2 and 3	2 and 3	4
Total wattage	9.0 kW	7.2 kW	7.3 kW	7.1 kW	12.0 kW
After					
Ballast quantity	100	80	100	100	100
Lamp type	4' (32W)	4' (32W)	4' (32W)	3' (25W), 4' (28W)	4' (34W)
	T8	T8	T8	T8	T8
Lamps per luminaire	3	3	2 and 3	2 and 3	3
Total wattage, normal operation	8.2 kW	6.6 kW	7.0 kW	5.4 kW	8.2 kW
Total wattage, load shedding engaged (1/3 reduction)	5.5 kW	4.4 kW	4.7 kW	3.6 kW	5.5 kW

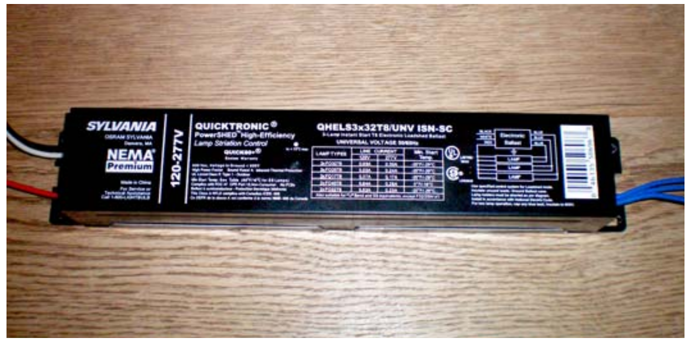
Field Test Results

Monitoring Results: Demand Reductions Achieved

DELTA researchers monitored the four New York City demonstration sites using electric meters installed at each distribution panel where a load-shedding ballast signal injector was installed. The electric meters continuously monitored electric loads and transmitted the data approximately every 5 seconds to an external server, via the Internet. Measurements of the electric demand were captured just prior to and just after the load-shedding ballast system was turned on each of the three times the system was initiated. Measurements were also taken just prior to and after the system was turned off. The average difference between the before and after readings were used to estimate the load reduction achieved by the load-shedding ballast system. Since there were other variable electric loads on the distribution panels, only an approximation of the load reduction achieved by the load-shedding ballasts was possible.

For the Welch Allyn (fifth) site, demand reductions were measured using a clamp-on ammeter on each of the distribution circuits containing load-shedding ballasts. These circuits also contained other variable electric loads. Ammeter readings were taken before the load-shedding ballast system was turned on and after the system was activated. The difference between the two readings was calculated as the demand reduction achieved. Again, since there were other electric loads on the distribution circuits, only an approximation of the demand reduction attributable to the load-shedding ballast system was possible.

The signal injector uses a ferrite core (donut-shaped object around the electrical cabling) to introduce the load-shedding signal to the building's wiring at the electrical distribution panel.



Load-shedding ballast

The anticipated demand reduction using the load-shedding ballast system was one-third of the normal lighting load (ballast and lamps), which is the fixed power reduction built into the load-shedding ballast. The measured demand reductions at the five sites were slightly less than the anticipated 33%. The measured reduction, on average, was 32%. The field test confirmed that the load-shedding ballasts operated as designed.

Monitoring Results: Response and Reporting Times

Testing of the load-shedding ballast system has shown it responded to a signal input via the Internet within ten seconds of the signal being initiated. Reporting of load reductions were observed to be occurring every five seconds. The load-shedding ballast system, as demonstrated, meets the response and reporting criteria of New York Independent System Operator (NYISO). However, the amount of lighting loads included in the system 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.

Monitoring Results: Illuminance Changes Due to the Load Shed Ballast System

When the load-shedding ballast system is engaged, power is reduced by one-third to the lamps, and illuminance is expected to also be reduced by one-third.

DELTA researchers measured illuminance using a calibrated, hand-held meter while the load-shedding ballast system was turned off and again with it on.

Measured illuminance reductions when the load-shedding ballast system was activated at interior work stations (away from windows) ranged from 21% to 37%.

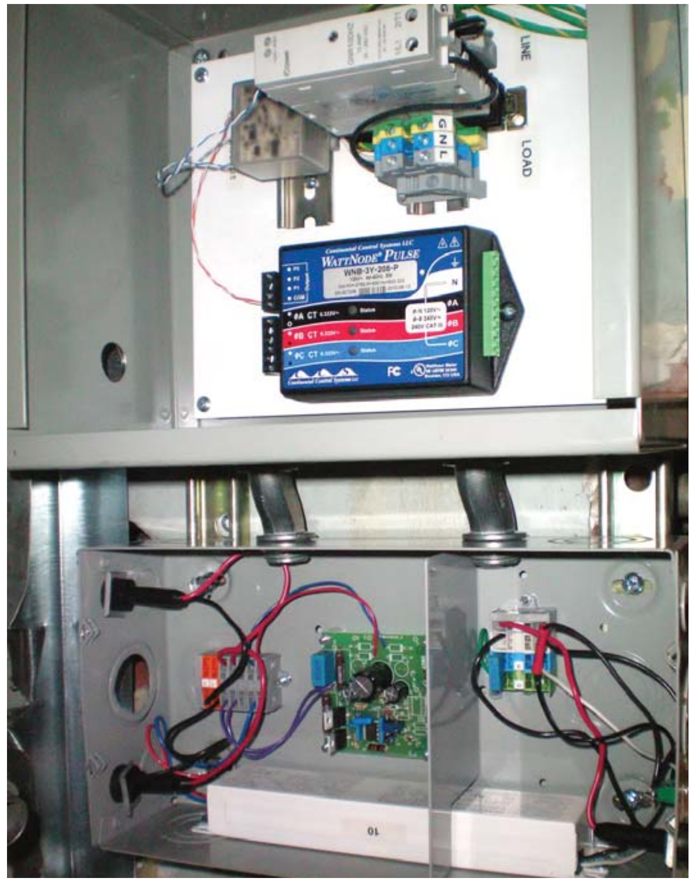
Occupant Feedback

Building occupants at all five demonstration sites were surveyed to determine their perceptions of the lighting systems under normal lighting conditions and with the load-shedding ballast system dimming the lights by one-third. The first survey was conducted prior to the load-shedding ballast system being activated. The second survey was conducted with the load-shedding ballast system in operation and the lights dimmed by one-third.

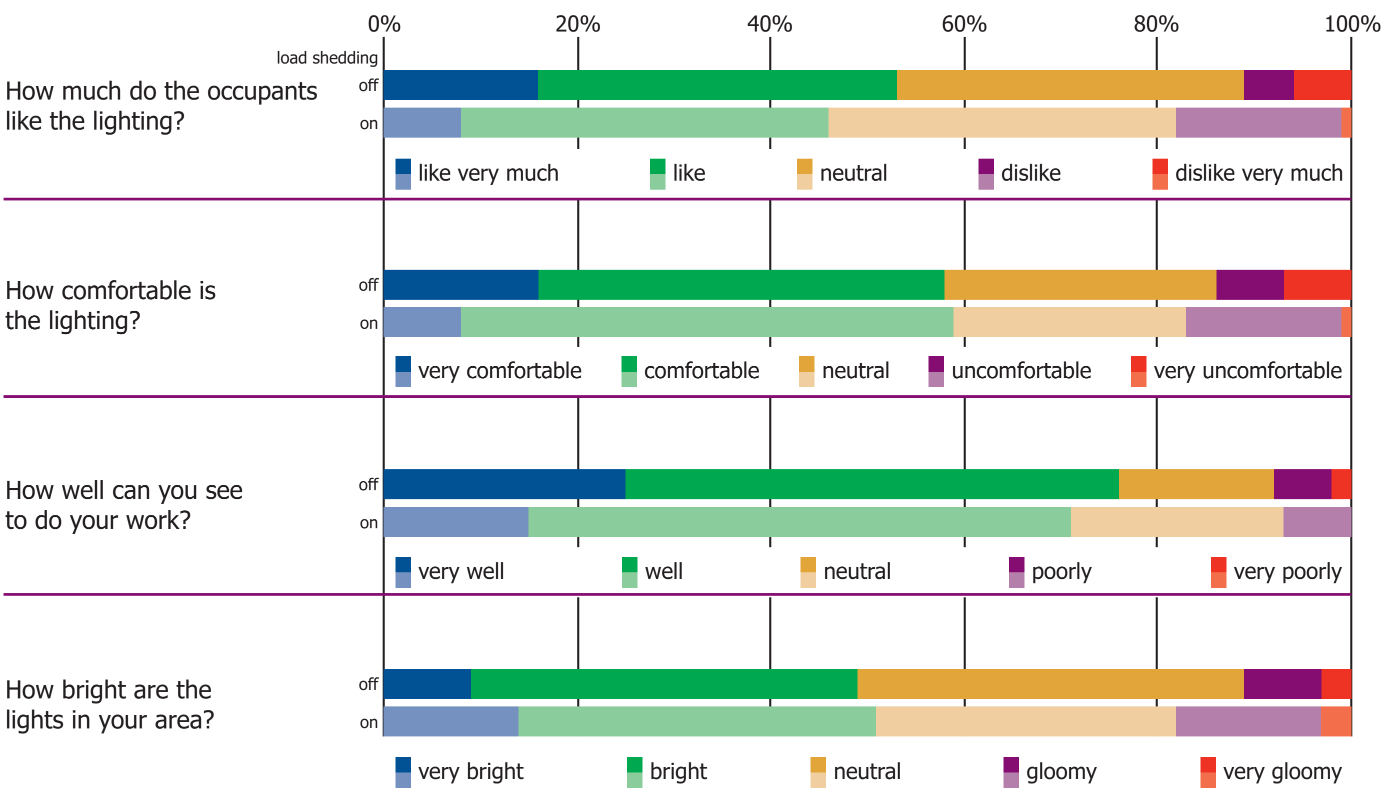
The figure below depicts the cumulative results from all demonstration sites. Results were similar at four of the five demonstration sites; only the Welch Allyn site was an outlier.

With the exception of the Welch Allyn site, this indicates an acceptance of the lighting levels provided when the load-shedding ballast system is in operation (lights dimmed). There was no significant change in the perception of lighting quality or quantity as related to how well building occupants could see to perform their assigned tasks between normal lighting conditions (no dimming) and the load-shedding ballast system in operation (one-third less light).

In the case of the Welch Allyn site, the load-shedding ballasts were located within a space where precision machining to very close tolerances is required. The one-third reduction in illuminance caused by load shedding was significant in a setting where critical tasks are being performed.



Two electrical boxes contain the communication gateway (top) and the signal injector (bottom).



Total respondents: Load shedding off, n = 113; load shedding on, n = 88

Installation Observations and Feedback

The installations at all five demonstration sites were performed in accordance with instructions provided by OSRAM Sylvania for both the load-shedding ballasts and the signal injector. Installers indicated the instructions were clear and installations occurred without any confusion. The load-shedding ballast installations were observed to take approximately ten to twenty minutes, the same timeframe as any other ballast change out. The time required for installation of the signal injector and the communication gateway varied greatly and was dependent on the mounting locations of the injector and gateway in relationship to the electric distribution panel. At the Welch Allyn site, the signal injector was installed in less than one hour because there were no obstructions to mounting the injector next to the distribution panel. At Yeshiva University, the installation took approximately two hours. At both City of New York sites, the installation time was about three hours because the injector and gateway had to be remotely located.

The installers indicated they did not incur any troubles with the installations of the ballasts, the signal injectors or the communication gateways, with the exception of Columbia University. At Columbia, the coupler was placed around the wrong set of distribution wires, causing the system not to work. Troubleshooting this situation corrected the issue.

Economic Analysis of the Load-Shedding Ballast System

There are at least four sources of potential benefits from the installation of the load-shedding ballast system. (See sidebar, right, for explanation of independent system operator [ISO] markets for demand response.)

- Reductions of monthly building peak demands, leading to reduced electric bills
- Participation in installed capacity (ICAP) programs sponsored by regional transmission and generation organizations/independent system operators, such as New York Independent System Operator (NYISO)
- Provision for spinning reserves for demand-side ancillary services programs (DSASP) sponsored by ISOs
- Participation in voluntary demand-response programs operated by utilities or ISOs

The table on the following page examines all four of these potential benefit streams for a load-shedding ballast system with a hypothetical 1,000 ballasts.

For new construction or replacement of existing T12 lighting systems, only the incremental cost of the load-shedding

Independent System Operator Markets for Demand Response

Installed Capacity (ICAP). In electric markets, companies that supply electricity to customers are required to procure either additional generation or the customers' willingness to reduce their electric loads to ensure sufficient capacity and energy are available to meet the reliability rules of the independent system operator (ISO). Customers willing to reduce their electric loads (demand response), usually through a curtailment service provider, and electric generating companies submit bids to the ISO to provide the necessary installed capacity. The lowest bids to meet the ICAP requirements are selected. There are penalties for non-performance. For more information see: **www.nyiso.com/public/markets_operations/market_data/icap/index.jsp**

Spinning Reserves. The ISO must ensure the reliability of the electric system against unplanned outages of either generation or transmission. Spinning reserves are relatively fast-acting (10 minutes or 30 minutes) sources of capacity, either generation or demand response (i.e., customers willing to reduce their electric loads), that can be brought online to make up for the loss of generation or transmission. The ISO requests bids from electric generating companies and demand-response entities, usually through a curtailment service provider, to supply the spinning reserve services. One such program is the demand-side ancillary services program (DSASP). The lowest bids to meet the spinning reserve requirements are selected. There are penalties for non-performance. For more information see: **www.nyiso.com/public/markets_operations/documents/manuals/operations/ancserv.pdf**

Voluntary Demand-Response Programs. Both transmission and distribution electric utilities and ISOs operate voluntary demand-response (DR) programs to ensure the reliability of their electric systems. If an emergency occurs where the demand for electricity is close to exceeding the capacity of the electric system to deliver that electricity or the generation capacity, a utility or ISO can request those customers who have volunteered to reduce their electric load to do so. Customers are compensated for their participation. There are no financial penalties if the customer does not perform. For more information, see: **www.nyiso.com/public/markets_operations/market_data/demand_response/index.jsp**

ballast system is included in the cost calculations. The remainder of the costs and the benefits to pay for these costs are associated with energy-efficiency improvements when changing to a T8 electronic ballast system. In the case where efficient lighting already exists, the full cost of installing the load-shedding ballast system must be offset by the benefits.

The benefit payment streams are greatly affected by demand charges included in utility rate structures and ISO payments for ICAP and DSASP. The higher the demand charges, the better the economic prospects for using the load-shedding ballast system. In the case of voluntary DR programs, the benefit stream is not guaranteed and may change each year depending on how many times a request is made to reduce loads.

These calculations assume installation in New York State. Costs and benefits for other locations will vary depending on utility electric rates, ISO DR program availability, and labor and material costs.

Economic analyses of the load-shedding ballast system

New Construction or Replacement of T12 Lighting

Customer Benefit Streams	Incremental Cost	Annual Savings	Simple Payback
Reduction of Billing Demand			
Con Edison (utility, NYC)	$14,340	$6,896	2.1 Years
National Grid (utility, upstate NY)	$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

Changing an Existing T8 Lighting System to Load Shedding

Customer Benefit Streams	Full Cost	Annual Savings	Simple Payback
Reduction of Billing Demand			
Con Edison	$56,000	$6,896	8.1 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

* - *Includes available incentives from New York State Energy Research and Development Authority (NYSERDA)*

** - *Assumes 20 hours per year of demand-response operation*

Findings

- Electricians characterized installation of the load-shedding hardware as straightforward.
- Demand-reduction goals were achieved.
- Response and reporting systems operated as intended.
- Most building occupants indicated they had sufficient light levels to complete their work when the load-shedding ballast system was engaged.
- Specialized operations where illuminance levels are critical, such as precision-machining areas, may not be suitable candidates for temporarily reduced lighting levels.
- The most advantageous economic outcome is associated with reducing a customer's demand billing, under current utility rate structures.
- The load-shedding ballast system can provide a reasonable economic return for new construction and when replacing older T12 lighting systems.
- The economic return when replacing existing, efficient T8 lighting systems with the load-shedding ballast system may exceed most customers' economic criteria.

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Field Test DELTA evaluates new energy-efficient lighting products to independently verify field performance claims and to suggest improvements. A primary goal of the Field Test DELTA program is to facilitate rapid market acceptance of innovative energy-efficient technologies.

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