Combining Distributed Generationand Energy Management Technologies to Achieve Energy Cost Savings

David A. Eberly, P.E. C.E.M.
Armstrong World Industries

ABSTRACT

Applying energy management systems to building control systems provides the capability to merge several conventional and non-conventional cost reduction strategies.

Energy consumption reductions are derived from conventional strategies such as temperature resets in air and water handling systems, chiller plant optimization, HVAC scheduling optimization, and automation of lighting system operation. These activities alone represent a significant potential for energy savings at a facility.

In the current era of deregulation, both the natural gas and electric utility suppliers find themselves in a changing and more competitive business environment. As a result, creative rate options have been developed to retain current customers and to attract new ones.

Electric utility rates, including RTP (real time pricing), and interruptible service (IS) have been available to PJM (Pennsylvania, New Jersey, and Maryland) customers since 1994. On-site power generation systems have been utilized by many facilities to take advantage of these rates to reduce electric costs. Energy management systems are also used to manage the operation of on-site power generation systems, conventionally for power outages or to improve power quality.

This article describes the installation of a 2,000 kW on-site power generation system, and the integration of its capabilities with a facility energy management system to exploit an interruptible electric service rate. These systems are installed at a 600-acre corporate campus site, located in central Pennsylvania. There are 28 buildings occupying the site, enclosing approximately 1,000,000 square feet of conditioned space.

By combining capabilities of the EMS (energy management system) and on-site power generation systems, the subject facility can interrupt more than *70 % of its on-peak summer electric load, within 2 hours after a curtailment request*, utilizing minimal staff, and causing minimal noticeable change to employees working at the site. The application of these systems has reduced the Campus annual electricity costs by more than 25% since implementation in July 2001.

FACILITY DESCRIPTION

Armstrong World Industries Campus Center and Corporate headquarters is located in Lancaster, Pennsylvania – the heart of the PA Dutch Tourist country. The Campus Center's facilities are located on a 600-acre plot, with approximately 150 acres of developed property including buildings, roadways, and parking areas. There are 28 buildings, enclosing just under 1,000,000 square feet of conditioned space for about 1,400 employees. The buildings currently range in age from those initially constructed in 1950 to latest Corporate Headquarters Building, #701, completed in Dec. 1998.

Facilities vary in construction techniques, envelope structure, and HVAC design. With the exception of Building 19, which houses the corporate data center, all buildings make use of a centralized steam plant for heating, and a 2,500 ton chilled water plant for cooling.

ELECTRICAL ENERGY SYSTEMS

Electrical power is purchased from the local utility at 13,800 volts and internally distributed to 21 different substations. The substations vary in size from 500 kVA to 3,750 kVA and are both indoor and outdoor types. Secondary power distribution voltages of 4,160 volts, 480, 277, and 208/120 volts are used. Peak electrical demands occur during the summer months, typically during July or August. In recent years, peaks of 4,800 kW have been recorded, always on a day when air conditioning loads peak.

There are seven (7) on-site emergency power generators, ranging in size from 7.5 kW to 750 kW (the data center generation) in addition to the 2,000 kW curtailment generator. These seven machines were originally installed to provide back-up power to building critical loads during power outages. The 750 kW data center system provides back-up power to a data center UPS (uninterruptible power supply), and is also used to shed approximately 450 kW of load during electrical curtailments.

ELECTRIC RATE INCENTIVES

The Campus is served by PPL Corp, a central Pennsylvania utility that is a member of the Pennsylvania, New Jersey, and Maryland (PJM) power pool. In the early 1990's, new interruptible rates were made available to large commercial and industrial customers, primarily those being served at 12 kV or 69 kV voltages. With the interruptible rates, customers pay reduced demand and energy charges, in exchange for an agreement to curtail power use to a firm kW target level when requested by the utility during designated periods of high demand or economic "hardship." In 1993, the Campus changed from the "firm" LP-4 rate to an interruptible rate. At the time the contract was executed, Armstrong opted for about 35% (1,500 kW) of the previous summer's peak demand for firm capacity. Table 1 shows the relationship of firm capacity to estimated savings.

Table 1. Interruptible Rate Comparisons

Rate	*Firm kW*	*Savings*	*$/kWh*
Firm Interrupt	100%	0%	$.062
	3,000		$.060
	2,500	6.6%	$.058
	2,000	14.7%	$.053
	1,500	19.6%	$.049
	1,000	26.2%	$.045
	0	36.0%	$.044

IS Rate Requirements

These are the general requirements of the rate:

- Negotiated "firm" power level
- Economic and mandatory interruptions

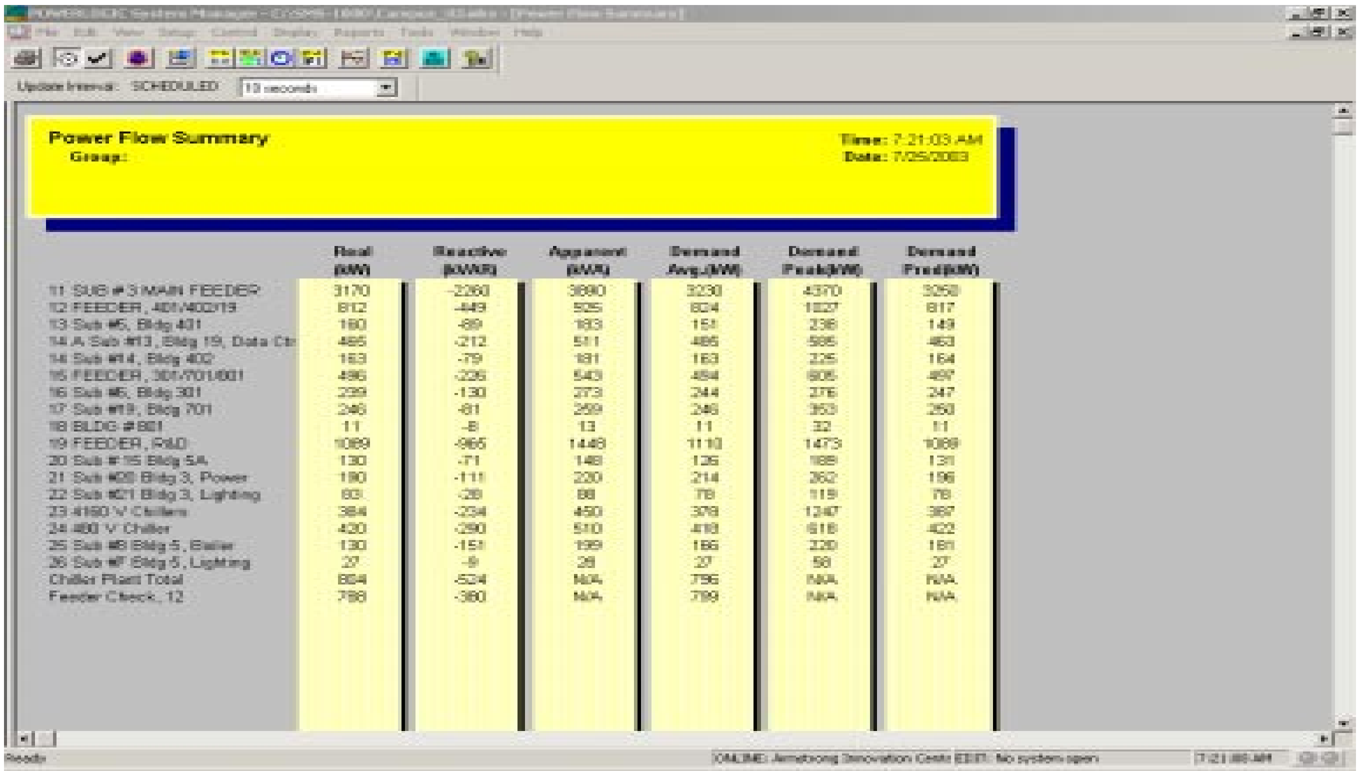
- Two hour curtailment notice
- Up to 15 interruptions per year, 10 hour maximum duration per interruption
- Five or less interruptions per month
- "Buy through" permitted for economic interruptions, LMP pricing for all kWh used
- penalties for not meeting firm level, reset firm level in billing until next mandatory interruption
- PJM emergencies *do not count* against the 15 tariff defined interruptions during a year

Manual, people-intensive curtailment procedures were developed to implement Campus wide equipment shutdowns to comply with the agreement. These included turning off discretionary lighting, non-centralized air conditioners, pilot line machinery, and certain test equipment. In addition, major electrical loads like chillers, air handlers, and pumps were also addressed by the procedures, sometimes at the expense of short-term staff comfort in occupied buildings.

Subsequent to adopting this power agreement, several Campus renovations and improvements were made. Among these was the construction and commissioning of a new 180,000 square foot corporate headquarters building (701). During the initial summer of building occupancy, the simultaneous occurrence of a mandatory electrical curtailment call and a Campus customer event, caused Armstrong to miss the compliance target in order to assure customer comfort. This non-compliance contractually reset firm demand levels under the agreement to 3,510 kW, essentially increasing electric costs to levels near the original LP-4 firm rate.

POWER MONITORING SYSTEM

In conjunction with the change to an interruptible power rate, Armstrong recognized that in order to manage a facility-wide electrical curtailment, some sort of real time power measurement system would be required. Initially, a six point personal computer-based system was installed at the Campus, replacing watt-hour metering at key substations. The system has subsequently expanded to include a total of 17 measurement points, including chiller plant and data center electrical power



Power Flow Summary
Group:
Time: 7:21:03 AM
Date: 7/25/2003

	Real (kW)	Reactive (kVAR)	Apparent (kVA)	Demand Avg.(kW)	Demand Peak(kW)	Demand Pred(kW)
11 SUB # 3 MAIN FEEDER	3170	-2260	3890	3230	4370	3258
12 FEEDER, 401/402/19	812	-449	925	824	1027	817
13 Sub #5, Bldg 401	160	-89	183	151	238	149
14 A Sub #13, Bldg 19, Data Ctr	465	-212	511	486	596	463
14 Sub #14, Bldg 402	163	-79	181	163	225	164
15 FEEDER, 301/701/801	496	-226	543	494	606	497
16 Sub #6, Bldg 301	239	-130	273	244	276	247
17 Sub #19, Bldg 701	246	-81	259	246	353	250
18 BLDG # 801	11	-8	13	11	32	11
19 FEEDER, R&D	1089	-965	1448	1110	1473	1089
20 Sub # 15 Bldg 5A	130	-71	148	126	189	131
21 Sub #20 Bldg 3, Power	190	-111	220	214	262	196
22 Sub #21 Bldg 3, Lighting	83	-28	88	78	119	78
23 4160 V Chillers	384	-234	450	379	1247	387
24 480 V Chiller	420	-290	510	418	618	422
25 Sub #8 Bldg 5, Boiler	130	-151	199	166	220	181
26 Sub #7 Bldg 5, Lighting	27	-9	28	27	58	27
Chiller Plant Total	804	-524	N/A	796	N/A	N/A
Feeder Check, 12	788	-380	N/A	799	N/A	N/A

Figure 1. Real Time Power Flow Table

loads. The PowerLogic® system allows anyone in the facilities group to monitor, in real time, all critical electrical loads, from the incoming main revenue meter to individual buildings, see Figure 1. This information is essential for managing interruptions that insure meeting the firm power target.

GENERATION PROJECT OVERVIEW

Given that the interruptible contract was still in place, but site decisions made since the agreement prevented cost savings, a generation project was evaluated. With an appropriately sized on-site generator, enough power could be made available to continue operation of key equipment, including the central chiller plant. The opportunity to reestablish and maintain lower electricity costs was achievable with generation.

An evaluation of equipment, both used and new was undertaken beginning in 1997. An ESCO, affiliated with the Southern Company, a major electric power provider to Armstrong in Florida, Georgia, Mississippi, and Alabama was selected to partner with Armstrong on this project. At the time, Southern was aggressively searching for businesses and locations to install site generation. They were involved in a similar project at a New Jersey business, geographically close to Armstrong's facilities in Lancaster. In April 2001, Armstrong purchased a 2 MW generation system, complete with step-up voltage substation and paralleling switchgear from Southern. The system was commissioned in July, and successfully operated during the initial utility *mandatory* curtailment called on Monday July 23, 2001.

Figure 2 shows the generation enclosure, a 2,500 kVA voltage step-up substation, and a 20,000 gallon #2 fuel oil tank, which is also the primary fuel storage for the Campus boiler operation.

Generation Specifications

- 2,000 kW Standby, 1,850 kW Prime rating
- 3,000 hp Detroit Diesel, 16 cylinder engine, fuel injected, turbo charged
- Marathon, 4-pole alternator, 480 volt output

- Kohler PD-100 integrated controller, LCD operator interface, automatic synchronism and paralleling operation
- Water cooled, 150 gallon glycol loop, 100 hp direct in line fan
- Fuel Consumption, 133 gal/hour at 100 % load

Energy Management Control System

The Campus employs a Johnson Controls Metasys® control system, initially installed for the corporate engineering building renovation in 1993. This system has grown today to incorporate controls for all subsequent remodels and new building construction. There are approximately 8,000 hardware and software points, controlled by 700 individually programmed processes. These processes control all HVAC functions for fourteen (14) buildings, the central chiller plant, and most recently, the boiler operation. In the boiler room, Metasys® monitors all critical mechanical systems, burner management systems, and steam parameters. It is Ethernet based, and is accessible from eight operator workstations around the Campus.

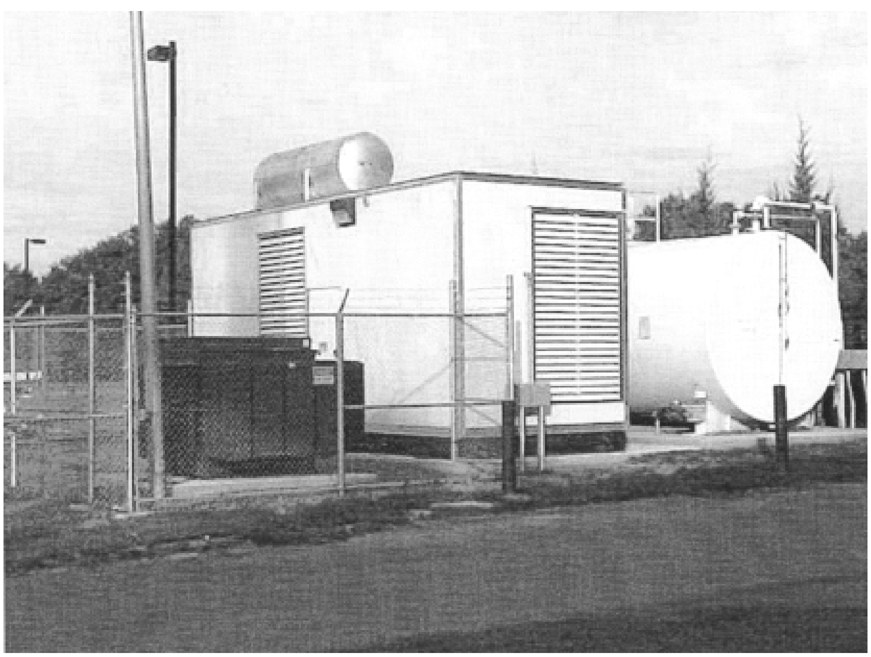


Figure 2. Generator, Substation, and Fuel Tank

Implementing a Curtailment

Since commissioning the curtailment generator in 2001, a curtailment process using Metasys® has been developed and optimized. Currently, the four-step process is accessed from any operator workstation by activating an icon on the desktop. In general terms, the process initially sub cools air-conditioned spaces by turning off all reheat systems. Next, dewpoint set points are adjusted upward so that discharge air temperatures go up, allowing chilled water temperatures to rise. The next step begins to override all chillers to an "off" state, except one 1,000-ton machine – which is manually controlled, depending upon actual chilled water (CW) temperatures. All building secondary chilled water pumps are slowed (variable speed drive operated) or shutdown. Main primary loop chilled water pumps are adjusted in the same way. These actions reduce chiller plant load from about 1,600 kW to 700 kW, some 55% before any electrical generation is placed on-line.

After these steps are implemented, on-site generation is started, about an hour before the power target (firm) must be reached. Depending upon actual power load before beginning the curtailment, only two generators are normally operated to reach the firm power level. First, the data center generation is placed on line, contributing about 450 kW. About 30 minutes before deadline, the 2 MW generator is placed on line. Using the power measurement system data, any additional adjustments necessary to meet target are made with Metasys® "tweaks." Additional building lighting, air handlers, and smaller water pumps may be shutdown. Figure 3 shows the overall contribution for each activity, and the significance of having on-site generation.

SUMMARY RESULTS

Electrical performance of the systems is shown. Figure 4 is a kW plot from the PowerLogic® system software that graphically shows the effect of all the actions just described. The date of this plot is important because it was the Campus' first opportunity to utilize the equipment after commissioning in July of 2001. Figure 5 is another plot from August 2001 for a consecutive three (3) day period when "mandatory" power curtailments were called by PPL. This plot demonstrates the repeatability of the curtailment process, and the site's ability to successfully implement it to met utility requirements. On each one of these peak days, the Campus shed more than 3 MW of load, in a 2-hour period using two

Metasys® technicians and an electrician to start and stop generators. Generation was operated for nearly 10 hours each day, usually off line and back to normal by 10:00 PM each night.

Electrical cost savings are summarized in Table 2. Prior to July of 2001, Campus electricity averaged $.061/kWh. After the first curtailment with generation, firm demand level was reset to 1,000 kW, under terms of the interruptible contract. Costs averaged $.046/kWh for the remainder of the year. Estimated savings for the two-year period since installa-

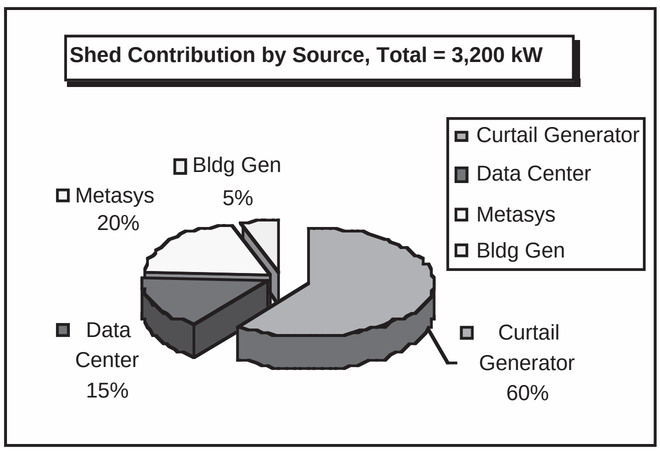


Figure 3. Shed Contribution

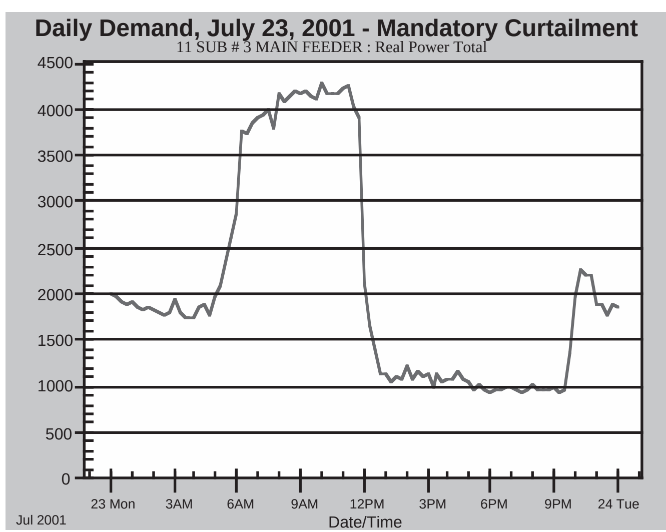


Figure 4. Curtailment Plot

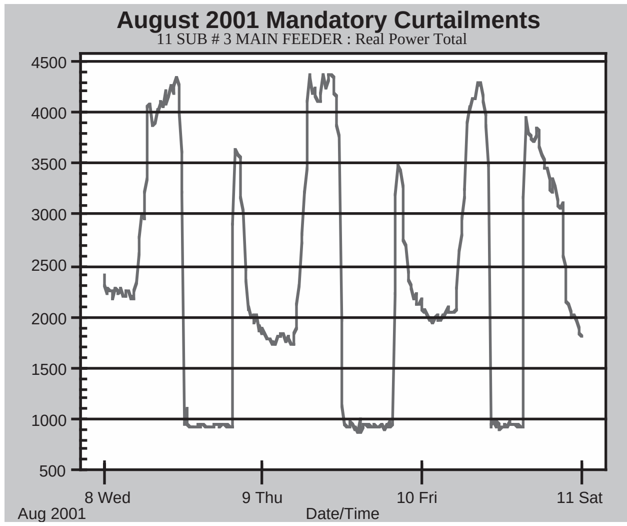


Figure 5. August 2001, "Repeats"

tion exceed $546,000. The $700,000 investment has yielded a 37% return on investment (ROI), less than 3-year simple payback. Working together, these systems reduce overall cost per kWh by 25%, when compared to buying on a non-interruptible rate.

Table 2. Interruptible Rate Savings

YEAR	*USAGE*	*Cost/kWh*	*$ Savings*
2001 (Jan-Jun)	11,659,000	$ 0.062	
2001 (Jul-Dec)	8,697,000	$ 0.046	$ 139,200
2002	20,439,000	$ 0.048	$ 286,200
2003 - Ytd	9,336,000	$ 0.049	$ 121,400
TOTALS			**$ 546,800**

FUTURE ACTIVITIES

In the spring of 2003, Armstrong evaluated participation in a new Power Pool program, the PJM Load Response Program. It is designed to provide an economic incentive to PJM customers to reduce load or run generation when electric pool (PJM) prices are high. There are three options to participate; two in real time markets, and a day ahead market option. While all three create new opportunities to use on-site generation to produce income, the day-ahead option has economic penalties for non-performance. Armstrong registered with a local Curtailment Service Provider in July 2003, to participate in this program's real time pricing options, until its conclusion in December of 2004.

CONCLUSION

The main purpose of an energy management system is to reduce energy consumption and cost while maintaining the highest level of customer comfort in the controlled spaces. A primary purpose for creating interruptible electric power rates is to provide customers an economic incentive to respond to high energy prices during periods of high demand. Combining capabilities of an EMS with on-site curtailment generation allows customers to take advantage of rate incentives, and to automate curtailment processes to be mostly transparent to facility occupants.

ABOUT THE AUTHOR

David A. Eberly, P.E., C.E.M. is a senior staff engineer in corporate facilities management for Armstrong World Industries, Inc., a global manufacturer of floor coverings, ceilings and cabinetry. At Armstrong for over 30 years, Dave has held several energy management positions including corporate energy engineer. He personally conducted energy audits at 12 domestic manufacturing plants, implementing conservation and efficiency improvement projects corporate-wide, and developed the corporate lighting improvement program, BRIGHT LIGHT$. He worked with energy purchasing to develop utility bypass projects including natural gas pipelines, cogeneration, and distributed generation installations. Dave is a graduate of the Pennsylvania State University with a B.S. in electrical engineering and an M.A. in business administration. Dave is also a registered professional engineer in Pennsylvania, a Certified Energy Manager (CEM), a member of ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) and a life member of the AEE (Association of Energy Engineers). Dave can be reached at daeberly@armstrong.com.