Permanent Distributed Load Reduction: A Bridge to Our Energy Future

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ABSTRACT

Access to reliable, low-cost energy is essential to national security and remaining economically competitive. Permanent Distributed Load Reduction (PDLR) is achieved via deployment of technologies at the point of use. Considering that up to 65% of prime energy is lost in the process of generating, transmitting and distributing electricity using traditional means, PDLR are distributed throughout the system, they are permanent, and they are economical.

Innovative technology to achieve PDLR is available in the form of high-performance lighting, wireless energy management control platforms and direct renewable solar day-lighting systems. When integrated, these technologies can deliver capacity to the electric grid – particularly during peak hours with remote access real time data and control at one's fingertips via mobile devices.

The technology has been proven in more than 6,000 commercial and industrial facilities throughout North America and has already delivered 574,000 kilowatts to the grid. The potential of PDLR is staggering.

If the inefficient lighting systems of the 455,000 commercial or industrial buildings across the U.S. not yet retrofitted, were replaced with high-intensity energy efficient lighting systems, more than 55,000 megawatts of power would be displaced – the equivalent of 111 coal-fired power plants.

As much as 81,000 megawatts (more than 160 power plants) of capacity could be delivered through the integration of energy-efficient lighting systems with wireless energy management controls and solar day-lighting technology. The cheapest power plant to build is the one that's never built. PDLR is a low-cost grid capacity solution that is the bridge to our future.

This work is an expansion of a previously published concept paper. From the original conceptual idea introduced in 2010, the following demonstrates a practical application of the important PDLR concept.

Introduction

"A revolution is unfolding." (Rosenburg 2011) With that simple four-word phrase, Neal Schmale, President and Chief Operating officer of Sempra Energy has aptly explained the sweeping and dramatic changes facing the electric industry today, changes that are "sudden, pervasive and radical."[1] In fact these changes will impact almost every way in which we interact with electricity and the electric industry – from the ways we produce and consume it to the ways we regulate and market it. The changes are fundamental re-workings of the energy industry and

[1] See definition of revolution at dictionary.com; available at: http://dictionary.reference.com/browse/revolution (accessed 16 February 2011).

they are intensified by both the sheer scale and reach of our electric system. Moreover, they are being and will be intensified because the electric industry has largely not experienced the kind of step-wise evolutions and modernizations that most other industries have experienced. Our power system and electric grid are aged, "the infrastructure necessary to generate, transmit, distribute and consume electricity was conceived and designed more than 100 years ago." (Bazmi & Koch 2010). To put it simply, the changes are presenting "the power industry with the biggest challenge it has ever faced" (Albuyeh & Ipakchi 2010).

Addressing these "sudden, complete or marked changes[2]" will likely require us to completely rethink how the electric industry market operates. (Albuyeh & Ipakchi 2010). To get a measure of how significant the challenges are, consider the following:

> *If Alexander Graham Bell were somehow transported to the 21st century, he would not begin to recognize the components of modern telephony – cell phones, texting, cell towers, PDAs, etc. – while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid. (DOE 2008).*

Rethinking Electricity

The fact that Thomas Edison who died eighty (80) years ago this October (Wikipedia 2011) would still be familiar with our electric grid and its operation suggests that the kind of transformative change that the electric industry is currently experiencing has probably not been faced, in this country, since the electricity industry itself was being born.

Responding to these changes requires us to fundamentally re-think the ways electricity is produced, consumed, regulated and marketed. We use electricity for everything, so these changes will impact our daily lives in real and material ways. In fact, "there is hardly any process in industry or application in private life that does not use electricity." (Bazmi & Koch 2010). These challenges will require us to move beyond our traditional accepted paradigm regarding energy consumption and production. We must develop the technology and solutions that allow us to consolidate our current paradigm with the game-changing 'killer apps'[3] that will fundamentally transform our relationship with the electric industry.

One of the ways our connections to electricity can be changed is the Permanent Distributed Load Reduction (PDLR) strategy developed by Orion Energy Systems. This strategy addresses our relationship with electricity, directed from the end-user perspective, by implementing solutions that both reduce energy consumption and add end-use sited energy generation at a commercial/industrial facility. PDLR strategies achieve these goals by incorporating base load energy-efficiency with innovative control strategies and customer-sited direct and generating renewable technology. In fact, the PDLR strategy, has the potential to become a true "killer app" for customers' relationships with the electricity industry by

[2] See definition of revolution at dictionary.com; available at: http://dictionary.reference.com/browse/revolution (accessed 16 February 2011).

[3] According to Wikipedia, a Killer Application (Killer App) has been used to refer to any computer program that is so necessary or desirable that it proves the core value of some larger technology, such as computer hardware, gaming console, software, or an operating system. A killer app can substantially increase sales of the platform on which it runs. Available at: http://en.wikipedia.org/wiki/Killer_App#cite_note-Killer_Application_Feb_1989-0 (accessed 16 February 2011).

fundamentally altering the consumption and production of electricity needed by American non-residential electricity customers. This has significant impacts because electricity represents one of the top 10 costs of doing business.

The Permanent Distributed Load Reduction Strategy

When multiple energy saving and renewable technologies are aggregated at an end-user's site to improve energy efficiency and reduce energy consumption, the resulting energy reduction is Permanent Distributed Load Reduction and generation (PDLR). PDLR is achieved via deployment of energy efficient and renewable technologies at the point of use. Point of use deployment is a critical component of PDLR since a key issue facing utilities and energy providers is a shortage of generation capacity.

The PDLR strategy has been developed in response to the significant challenges facing the electric industry, and as such it can serve as a critical bridge between our current electric system and that which will be born of the revolutionary changes that are occurring. The challenge we are facing is simply put, "electric power is a critical element of our economy." (Albuyeh & Ipakchi 2010). Yet the reliability and availability of this critical element is threatened by an electric infrastructure that was designed and built around models that did not anticipate nor account for the rapid expansion of electrical consumption by commercial businesses and even more critically, the explosion of residential electricity consumption,[4] as can be seen in Table 1 below.

Table 1: Electric Consumption by Sector (Million MWh), Selected Years

Year	Residential		Commercial		Industrial		Total
	Used	% Total	Used	% Total	Used	% Total	
1979	683	33.0%	543	26.3%	842	40.7%	2,068
1984	780	34.2%	664	29.1%	838	36.7%	2,282
1989	906	34.3%	811	30.7%	926	35.0%	2,642
1994	1,008	34.4%	913	31.2%	1,008	34.4%	2,930
1999	1,145	34.6%	1,104	33.4%	1,058	32.0%	3,307
2004	1,292	36.5%	1,230	34.8%	1,018	28.8%	3,540
2009	1,363	38.5%	1,323	37.1%	882	24.7%	3,568

Source: United States Energy Information Administration ,"Table 8.9 Electricity End Use, Selected Years , 1949-2009" Annual Energy Review 2009, Washington, DC: United States Department of Energy, 2009, p. 259.

In fact, between 1979 and 2009, almost all electricity growth in the United States was driven by the residential and commercial sectors which grew by 100% and 140% respectively over the period. Industrial energy use, on the other hand, grew by only 5% between 1979 and 2009. (Albuyeh & Ipakchi 2010). As the electricity demand of residential and commercial customers has grown, industrial energy consumption has become a less important driver of US electricity consumption, dropping from almost 41% of total consumption in 1979 to under 25%

[4] For example, see Ipakchi and Albuyeh, p. 57; "Most distribution systems in the United States were designed decades ago based on the loading analysis performed at the time. Major changes in load levels and load patterns [like those driven by the increasing electrical use in our homes] may require upgrades to the transformers and other equipment or changes to the switching configuration shifting loads between transformers"

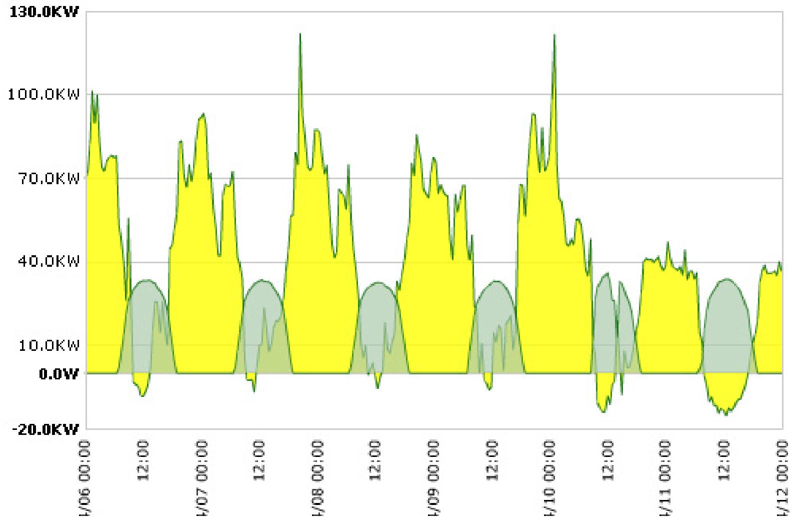
in 2009. (Albuyeh & Ipakchi 2010). Therefore, while an electric infrastructure based on demand projections from 1979 is likely adequate to serve the needs of the 2009 *industrial* sector, it is woefully underprepared to serve the needs of the modern demand for electricity. In their research published in *IPEE power & energy magazine*, Farrokh Albuyeh and Abi Ipakchi of Open Access Technology International have found that "many distribution circuits have been operating close to their operating limits." (Albuyeh & Ipakchi 2010). Therefore, it is critically important that we develop and implement solutions that can allow us to reduce the stress on the overall infrastructure of the electric system. This is especially true as we continue to add significant new sources of consumption like plug-in electric vehicles and cloud data centers, which consume exponential amounts of power and which could strain our electric infrastructure beyond its limits.[5] For example, as noted by Lee Krevat, Director of Smart Grid for San Diego Gas & Electric, charging an electric car can consume as much energy as a traditional home. (Schlesinger 2010). Steiner Dale, Director Florida State University Center for Advanced Power Systems has suggested that, "if everyone who owned an electric-power car recharged it at the same time, the grid would crash." (Schlesinger 2010). Addressing grid congestion and creating a bridge to our energy future is critical as "poor reliability can cause huge economic loses." (Santacana et al. 2010). According to the Department of Energy, "power outages and interruptions cost Americans at least $150 billion each year, or approx. $500 for every man, woman and child." (DOE 2008). By fundamentally transforming how non-residential customers are supplied and consume electricity, the PDLR strategy is ideally positioned to be a key solution to our growing infrastructure constraint challenges.

Real Life Application of PDLR

In theory this discussion sounds great, but as with all theories, the proof is when strategies like PDLR are put into practice. Consider, as an example, the PDLR experience of a major manufacturer, one of Orion Energy Systems' customers. As part of a multi-phase rollout at their hundreds of production and distribution sites, the company has begun implementing an aggressive PDLR strategy that integrates energy efficient lighting, motion and ambient light control, direct solar illumination and solar photovoltaic generation. This PDLR strategy, in addition to ancillary demand shifting, provides significant peak load reduction. The actual results from the customer's PDLR strategy can be seen in the following chart.

[5] New data centers are being built to keep up with the constant stream of information we produce. According to the latest figures, data centers represent 1.5% of world total electricity consumption. http://bizcloudnetwork.com/2010/cloud-computing-to-reduce-data-center-energy-consumption/

Chart 1: Customer Load Profile



yellow peaks = metered use
green bumps = solar generation

PDLR step 1. As demonstrated in the chart above, by integrating energy efficiency, dynamic controls, direct solar illumination and solar electric generation, PDLR has resulted in a significant positive impact on the customer's usage of electricity. When employed in concert with an aggressive load shifting strategy, the customer has been able to reduce facility consumption to zero during many peak periods, going so far as, in some cases, to become a net generator of electricity for the local electric system. Consider that there are over 650,000 manufacturing and warehouse facilities in the United States. (EIA 2008). If all these facilities employed a similar PDLR strategy to the one highlighted above – with or without aggressive load control strategy – this would have a significant impact on both our electrical system and the larger economy.

While energy efficiency may not be considered as exciting nor often as marketable as renewable energy activities, it will always be the core of any truly effective PDLR strategy. In the PDLR strategy, energy efficient measures include high-performance lighting, compressed air, HVAC, and process efficiency, among others. More specifically, Orion's PDLR strategies are grounded in the lowest of the low-hanging fruit of energy efficiency – lighting. (Chu 2010). Since the 1930s when the fluorescent lamp was introduced (Bellis 2011), and the 1960's when the Metal Halide fixture was introduced (Williams 1999), the options for commercial/industrial lighting have remained relatively unchanged, and, therefore, many customers don't realize there are alternative lighting options. Through proprietary design, and by incorporating recent advancements in lighting technology, Orion Energy Systems has developed a unit that reduces overall fixture consumption (by maximizing reductions in heat and vibration) by approximately 50%, while at the same time improving overall light levels in a facility by approximately 50%. With this technology, customers gain significant reductions in their overall energy consumption, while experiencing dramatic improvements to workplace illumination as demonstrated in the customer examples below.

Picture 1 – Manufacturing (Before)

Picture 2 – Manufacturing (After)

Displaced Capacity	Displaced Energy	Energy Bill Reduction	CO_2 Removed
172.3 kW	1,185,140 kWh/yr	$60,544/yr	778 tons/yr*

*Based on EGRID 2007 v1.1

Picture 3 – Warehouse (Before)

Picture 4 – Warehouse (After)

Displaced Capacity	Displaced Energy	Energy Bill Reduction	CO_2 Removed
62 kW	222,549 kWh/yr	$15,690/yr	146 tons/year*

*Based on EGRID 2007 v1.1

PDLR step 2. The second component of an effective PDLR strategy is load control, particularly peak load control. Growth in peak demand has been driven by population growth, the supersizing of homes and electronics and the increasing digitalization of the economy.[6] In turn, this growth in U.S. electricity demand has outstripped growth of transmission capacity by almost 25% per year. (DOE 2008). The importance of reducing peak load consumption is described in a white paper on energy costs by ISO-New England:

[6] "Since 1982, growth in peak demand for electricity – driven by population growth, bigger houses, bigger TVs, more air conditioning and more computers, has exceeded transmission by almost 25% every year." DOE, Smart Grid, 6.

> Current load profiles require substantial investments for serving load during only a handful of hours each year. Reducing demand in the handful of hours can have a disproportionate impact on infrastructure needs. (ISO- New England 2006).

The Department of Energy quantifies 'a handful of hours each year' as less than 400 or roughly 5% of the time.[7] In other words, peak control and system management can dramatically reduce demand, in turn reducing the stress on our taxed transmission and distribution infrastructure thereby reducing the need for new infrastructure and/or allowing us to serve greater amounts of demand without expanding our existing infrastructure.

In its project experience, Orion has encountered many companies that had already taken measures to manage energy consumption with the installation of energy control systems only to disable them because they were 1) difficult to program, 2) unreliable in operation, or 3) inflexible in responding to a building's changing uses and needs. The key to success with Orion's PDLR strategy is its dynamic wireless control and monitoring system which provides centralized management of energy needs. Using an interface similar to an electronic calendar, time of day scheduling/programing operates reliably and can be easily re-configured and redesigned in the field to respond to the real-time changing uses and flows within a facility. In addition, the Orion control system can interface with, monitor and track the operation of any general electrical device connected to it – whether light fixtures, HVAC equipment, fans, or compressed air systems. The detailed energy profile provided by the system allows companies to manage their measured energy consumption and respond to real-time changing needs and opportunities – be they facility usage, demand response programs, or time-of-use price signals from their utility.

PDLR step 3. The third component of Orion's PDLR strategy is the integration of direct solar illumination in conjunction with the electric lighting system. A direct solar illumination system can be integrated with either legacy or energy efficient lighting systems via the control system which measures light levels and adjusts fixture operation accordingly. The direct solar illumination system allows companies to employ ambient light to illuminate their facilities and displace their traditional electricity consumption during peak periods when the strain on the electric grid is the greatest. Moreover, with the integration of control and monitoring technology, a customer's illumination system (both electric and direct solar) can be designed to ensure that facility light levels meet and/or exceed the customer designed and established protocols for their lighting needs. Additionally, unlike traditional skylights and/or windows, direct solar illumination devices, like Orion's, can be positioned like traditional light fixtures. This allows customers to design the integration of their electric and direct solar illumination light systems to maximize their use of ambient light and the associated savings from reduced electricity consumption.

[7] "10% of all generation assets and 25% of distribution infrastructure are required less than 400 hours per year, roughly 5% of the time. " DOE, Smart Grid, 19

Picture 5: Orion Electric Illumination

Picture 6: Orion Direct Solar Illumination

As seen in the photographs above, the direct solar illumination component of a PDLR strategy can provide enough ambient light to shut off a facility's electric lights during peak periods. This, in turn, lowers the facility's electric consumption and the overall stress on the electric infrastructure during peak periods when demand is greatest and reliable services most critical.[8]

PDLR step 4. Finally, the fourth component of PDLR strategy is the integration of end-user sited generating renewable technology. One of the key challenges with traditional renewable generation is getting the generated power from its centralized, large-scale generation site to the various and disparate consumption sites via transmission lines and distribution infrastructure. In fact, in the case of the wind-power market, the wind generating capacity "is poised to outstrip the capacity of the high-voltage lines to send the electricity." (Davidson 2008). This threatens to create significant bottlenecks in our transmission grid that will limit our ability to move power from where it is being generated to where it is being consumed. Direct-use end-user-sited renewable generating technology, on the other hand, incorporates site-appropriate renewables on the customer's site that feed directly into the facility.

Capacity acquisition is achieved via PDLR through energy efficiency, direct-use renewables and distributed energy generation – including solar photovoltaic, solar water heating, Urban Wind, geothermal systems, and biomass/gas systems -- by delivering renewable energy directly into the system without the transmission and distribution losses associated with traditional generation. Additionally, the introduction of customer-sited renewables has the potential to increase the renewable generating capacity for the local utility/community as PDLR can shift customers from being net consumers to net generators of electricity during peak periods of the day, as seen in the customer experience presented above.

[8] Uninterrupted and reliable power supplies are essential for successful manufacturing operations. Consider the case of Toshiba's Yokkaichi memory-chip plant[8] in Mie Prefecture, Japan which experienced a critical power loss for a mere 0.7 seconds. That momentary loss of power forced production systems offline. Such an unexpected shutdown can damage data and programs on the systems affecting the whole production line and leading to a 20% reduction in shipments for two months. (Erodov.com 2010).

Summary

The potential impacts of broad implementation of PDLR strategies are significant. There are approximately 650,000 manufacturing and warehouse facilities in the United States today. (EIA 2008, 2010). Based on Orion's project experience with its over 6,500 customers across the country, the average manufacturing-warehouse facility, which averages between 75,000 and 80,000 square feet in size, uses approximately 200 illumination fixtures that operate on average 7,500 hours per year.[9] Controlling each of those fixtures will reduce operation by 25% per year conservatively. Additionally, for most facilities, 20% of the installed fixtures can be displaced with solar illumination devices for approximately 1,500 hours per year conservatively. Finally, typical project experience has conservatively suggested that 5% of a facility's roof could be retrofitted with a white roof and solar panels to generate on-site electricity.[10] The following chart shows what this means for an average building, and potential for the manufacturing/warehouse market.

Table 2: PDLR Results[11] – Average Building

PDLR Overview		Base Load Reduction		Peak Load Displacement	
Technology	**Count**	**kW**	**kWh**	**kW**	**kWh**
Fixtures	200	48.8	366,000		
Controls – No Ambient	160			0	66,000
Controls - Ambient	40			0	3,300
Ambient Solar Illumination	40			9.8	14,640
Solar Photovoltaic Generation	148			25.6	38,444
Totals		48.8	366,000	35.4	122,384

Implementing the PDLR strategy at an average facility will yield a reduction in baseload demand of over 45 kW, and reduce total energy consumption by over than 360,000 kWh per year. PDLR delivers an additional reduction in peak load demand of over 35 kW and over 120,000 kWh.

The key take away from this example is that the average facility, prior to implementing PDLR, consumed over 90 kW at peak per year compared with post PDLR implementation when, at peak times, the same building will consume approximately 10 kW, freeing over 80kW of capacity for the system to use *when the capacity is most needed*. Moreover, the facility's use of energy is reduced from almost 700,000 kWh per year to only just over 200,000 kWh per year, a reduction of 70%. Extended to the some 650,000 buildings in the manufacturing and warehouse sectors – this would translate into, on average, a base load reduction in demand of 31,720 MW,[12] or the output of 64 average base load coal power plants (at 500 MW/plant). In addition,

[9] In its project experience, Orion has found that most facilities have one fixture for every 400 square feet.

[10] For the purposes of discussion, Orion uses 173 watt solar panels (installed on the company's own roof), although panels can extend from 100-220 watts. These panels take up approximately 30 sq. ft per panel.

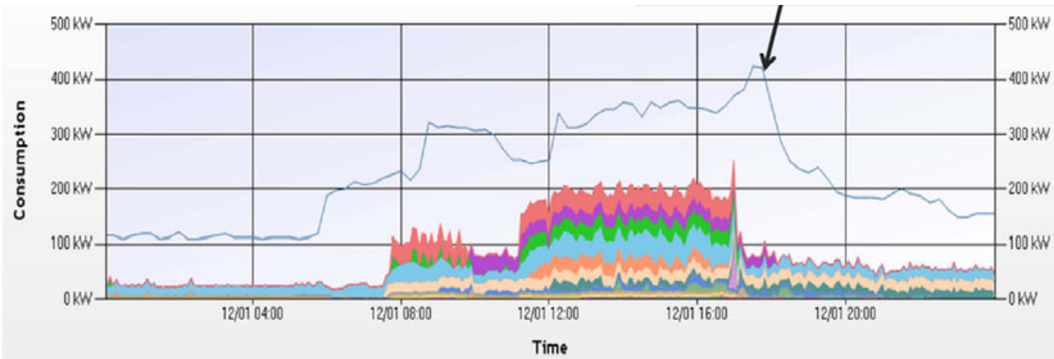
[11] As noted in the description, the assumptions for this model are conservative compared to what Orion has observed in its own PDLR working model. For example, Orion's experience has suggested that control strategy will typically allow closer to a 50% reduction in consumption, ambient reductions are typically on the order of 2,000 hours per year, and solar panels tend to be installed on 10-20% of a facility's roof. In the interest of showing a conservative and non-proprietary model, the savings were reduced to the numbers used in the analysis.

[12] 650,000 Buildings * 48.8 kW per building = 31,720,000 kW; 1,000 kW = 1 MW.

the PLDR as proposed above would provide an additional 23,364 MW of peak capacity to efficiently, safely and reliably meet our nation's escalating demands for electricity and significantly reduce the strain on the nation's generation and distribution infrastructure.

The theoretical calculations are impressive, but, as it is with every energy solution, the question is does it work? Below is a chart of the energy consumption for Orion Energy Systems corporate campus in Manitowoc, Wisconsin.

Chart 2: Orion Campus Energy Consumption



The arrow indicates the total required load line (approx. 420kW), which shows the plant's base load electric consumption. Orion has deployed energy efficient equipment in its lighting, HVAC and compressed air systems. The controls and solar illumination technology further reduce that load by another 134 kW – leaving approximately 285 kW of demand during peak periods. The facility also has 250 kW of solar generation and 70 kW of wind generation installed on site. Therefore, during those peak periods when energy is most needed, Orion's facility is at best a net generator adding approximately 30 kW to the grid, or at worst, is consuming 35 kW rather than the 420kW that it would otherwise need without its PDLR strategy.

Conclusion

Clearly the PDLR strategy, as developed by Orion Energy Systems, demonstrates that the effective integration of energy efficient equipment, controls, direct-use renewables (i.e. solar water heating, solar illumination), and traditional renewable generation, can provide real, sizable and significant load displacement necessary for bringing relief to our nation's taxed generation and distribution infrastructure. This revolutionary concept comes at a moment when we need it the most, as unsustainable load growth threatens the very stability of the system itself. Developing extensions of the strategy across the country and incorporating assorted renewable and energy efficiency technologies will expand the effectiveness of PDLR and bring real, immediate and material benefits to all involved parties. Implementing customers will realize significant changes to consumption and acquisition of energy which translates into tangible bottom line benefits. Utilities and regional grid operators capture additional generating capacity without the cost and challenge of constructing new generating, transmission or distribution infrastructure. All ratepayers capture the benefits of capacity expansion at a lower cost than through traditional generation expansion and from reduced carbon emissions and other harmful pollutants. The PDLR strategy is a “killer app” that will help us bridge the gap from Thomas Edison’s electric system to the critical energy solutions that will be developed in the future.

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