Smart Grid Opportunities for Data Centers

July 16, 2010

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Outline

- Demand Response Research Center (DRRC)
- Electricity Value Chain
- Linking Data Centers and Smart Grid
  - Smart Grid, Demand Response, and Automation
- Project: Data Center DR Opportunities
  - Characterizing Load/ Technology/ Metrics
- Results
- Data Center Value Proposition

LBNL Demand Response Research Center (DRRC) Research Areas

- Funded since 2004 by **California Energy Commission** plus US DOE, Bonneville Power Administration, NYSERDA, Seattle City Light, PG&E, SCE, SDG&E, SMUD, etc.
- Topics organized into 3 categories:
  - **Energy Systems Integration and Strategic Issues**
    - **Valuing Demand Response**
    - **Dynamic Tariffs and Rate Design**
    - **Communications Infrastructure**
  - **Buildings**
    - **Automation, Communications and Control/IT Systems**
    - **End-Use Control Strategies and Models**
    - **Behavior –response to dynamic tariffs**
  - **Industry**
    - **Automation, End-Uses and Control/IT Systems, Strategies**

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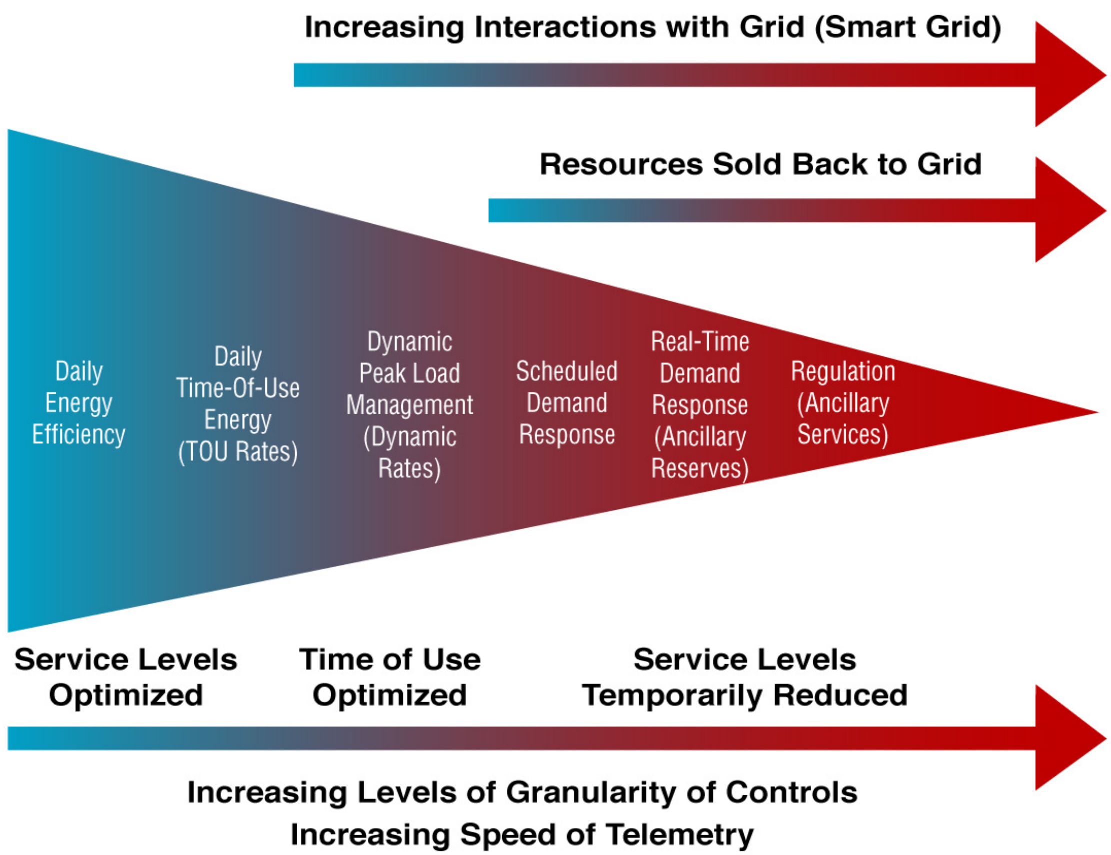
Electricity Value Chain: Linking EE – DR

- Maximizing time scales, technology, services.



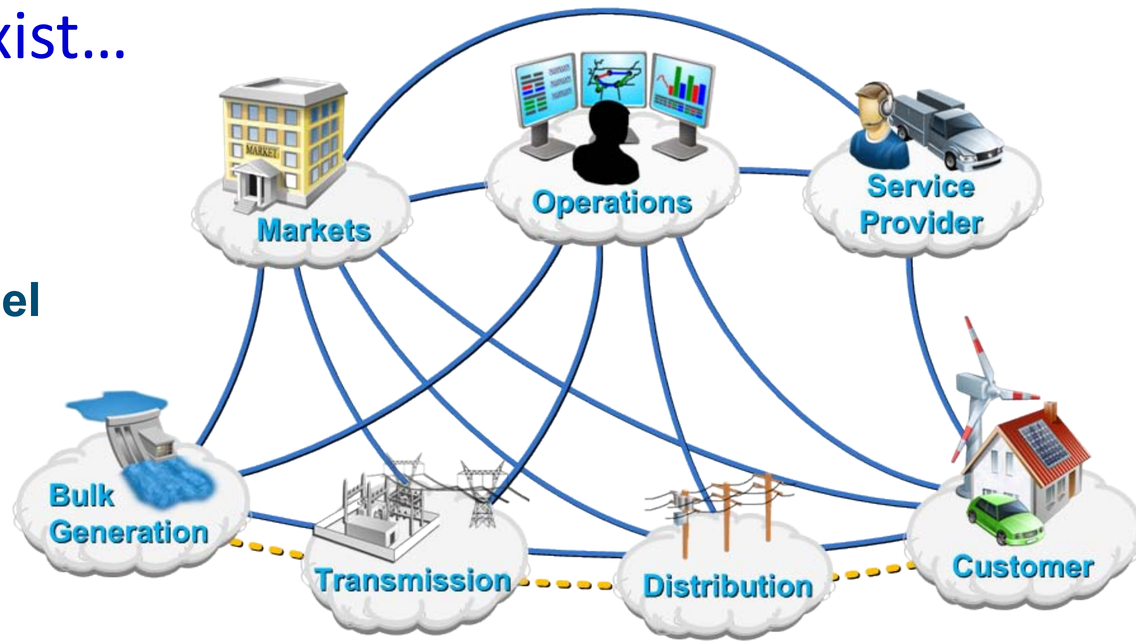
Linking Data Centers & Smart Grid*

- Dynamic optimization of grid operations and resources
- Incorporation of demand response and consumer participation

Measurement → Visualization → Automation

- Other definitions exist…

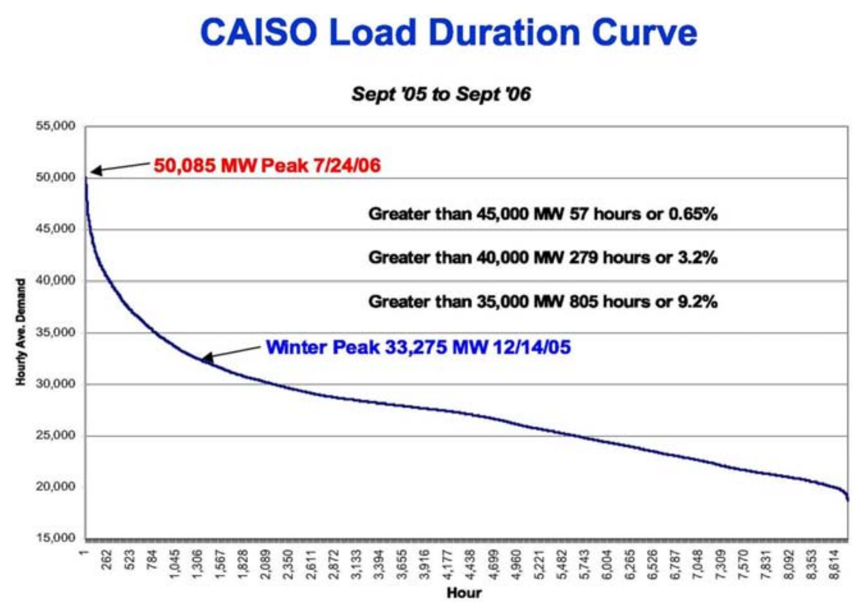
Smart Grid Conceptual Model



* **DOE Secretary Dr. Steve Chu's presentation:** GridWeek 2009: http://www.pointview.com/data/2009/09/31/pdf/Steve-Chu-4774.pdf

What is DR?

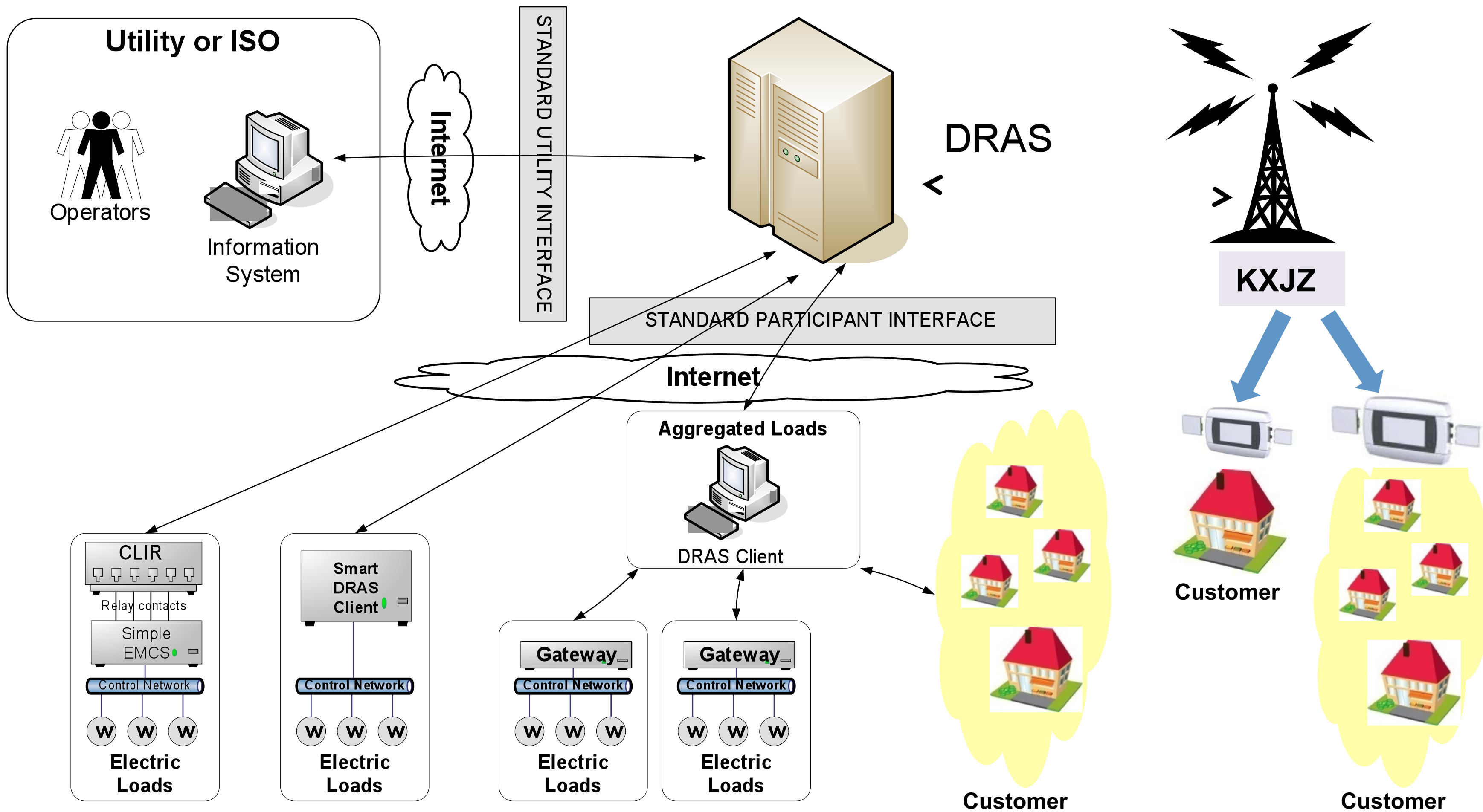
- Demand Response NOT Disaster Recovery (Can prevent though).
- A set of actions taken to reduce electric loads when:
  1. Contingencies, such as emergencies or congestion, occur that threaten the supply-demand balance OR
  2. Market conditions occur that raise electric supply costs.
- The goal is to improve electric grid reliability and lower use of electricity during peak demand



Data Centers and DR, Automation

- Increase knowledge of what, where, for how long, and under what conditions industrial facilities will shed or shift load in response to a notification;
  - Develop a better dynamics of maximizing load reduction savings without affecting operations;
  - Facilitate deployment of the industrial Auto-DR that is economically attractive and technologically feasible; and
  - Effectively target efforts to recruit industrial Auto-DR sites
- Try DR first!

Open Auto-DR Architecture



Commercial and Industrial Customers

Residential – Small Commercial Customers

Project: Data Center DR Opportunities

- **Goals:** Investigate data center characteristics, loads, control systems, and technologies, identify DR and Open Auto-DR opportunities/ challenges.
- **Methods:** Collect & analyze existing C&I research, evaluate and characterize load shapes, issues, identify DR opportunities/ challenges and key strategies/ technologies, and OpenADR scenarios.
- **Findings:** On the basis of operational characteristics and energy use, data centers have significant potential for DR.
  - Excellent candidates for OpenADR.
- **Next Steps:** Field tests/demos.
- Report: http://drrc.lbl.gov/pubs/lbnl-3047e.pdf

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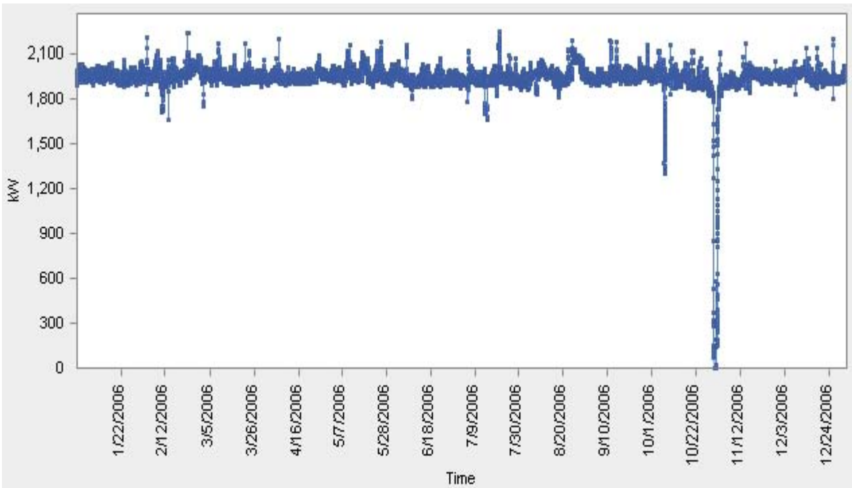
Load Characterization

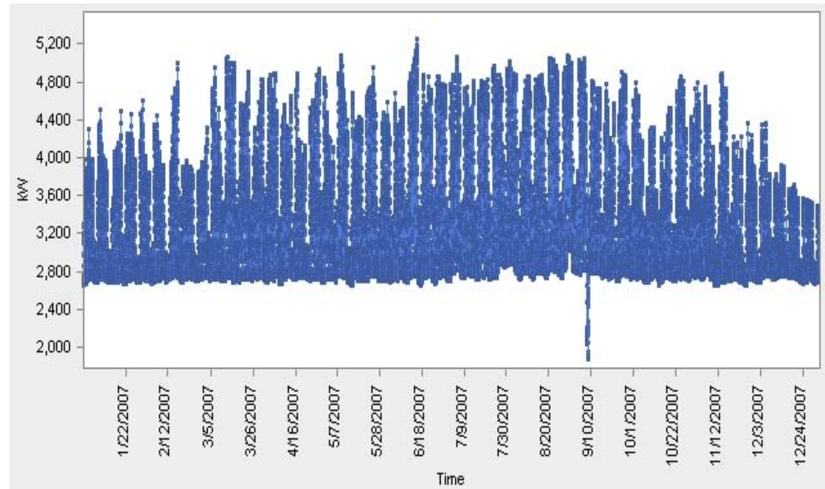
- Daily Load Factor (DLF):
  - Determine load variability (Flat vs. Mixed-Use)

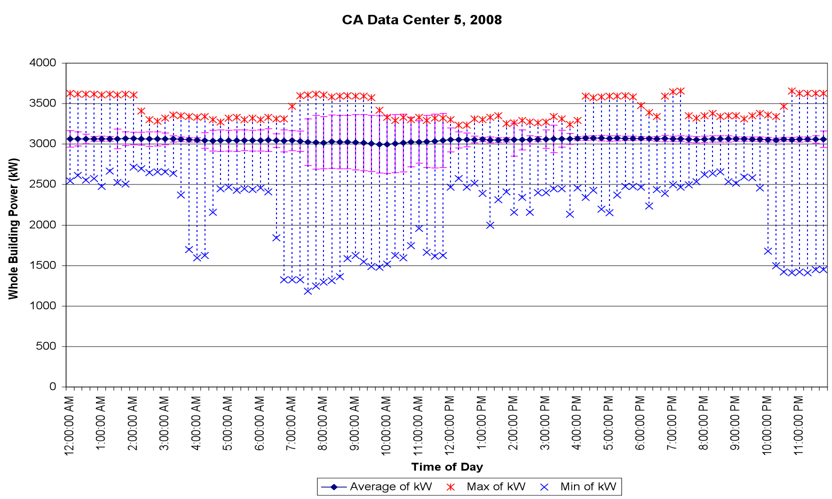
$$AvgerageDLF\% = \frac{AvgerageDailyIntervalLoad}{MaximumDailyLoad}$$

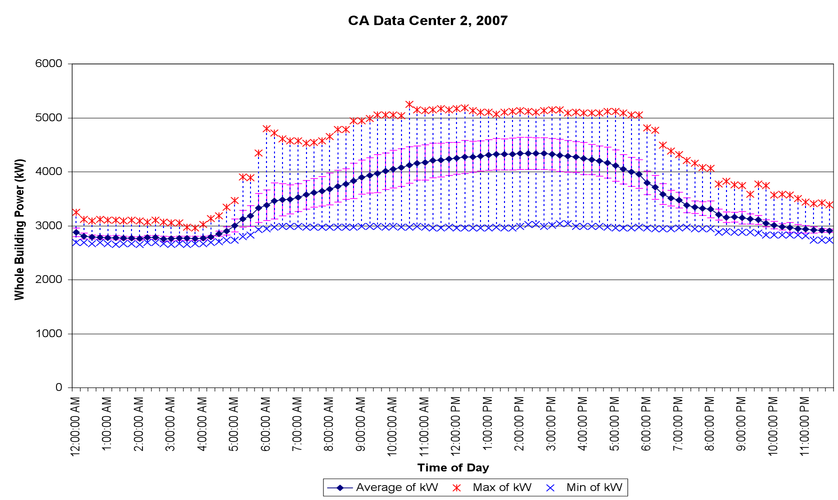
Data Center	Data start	Data end	Load shape	Average DLF
CA Data Center 1	1/10/2008	9/2/2008	Flat Load	98%
CA Data Center 2	4/6/2003	Current	Mixed-Use Load	81%
CA Data Center 3	4/6/2003	Current	Flat Load	95%
CA Data Center 4	7/21/2005	Current	Flat/ Mixed-Use Load	83%
CA Data Center 5	4/6/2003	Current	Flat Load	99%
CA Data Center 6	1/29/2005	Current	Mixed-Use Load	88%
CA Data Center 7	4/6/2003	Current	Flat/ Mixed-Use Load	89%
CA Data Center 8	4/6/2003	Current	Mixed-Use Load	83%

Load Characterization





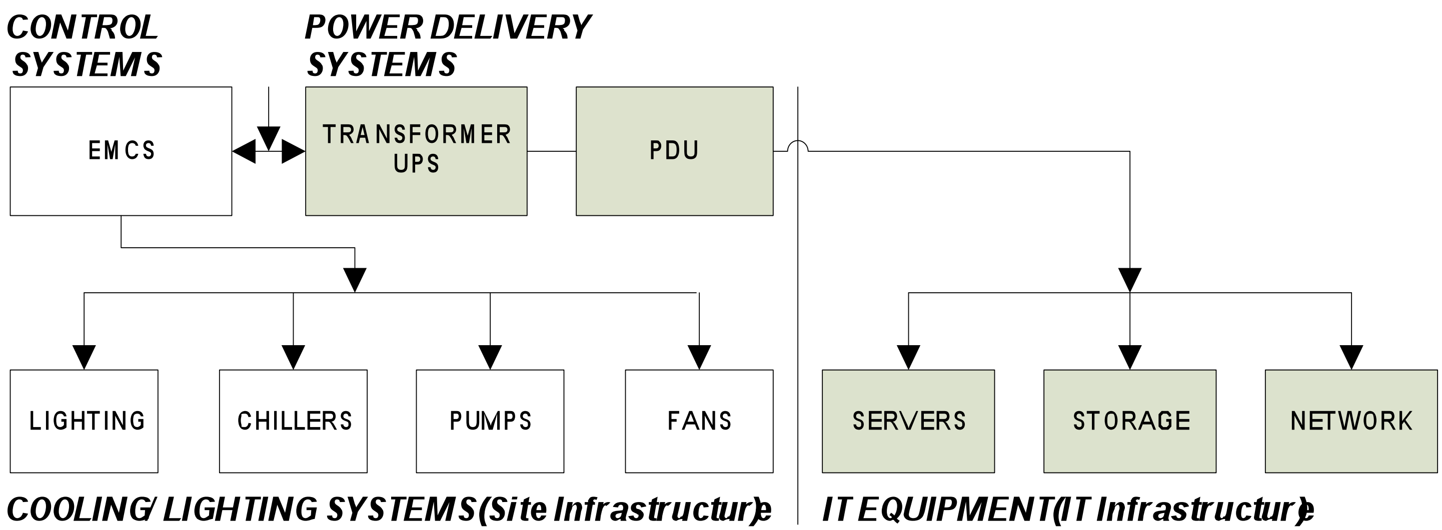




Flat Load (Avg DLF >=90%)

Mixed Use (Avg DLF <90%)

Technology and Energy Metrics



- Physical Server Reduction Ratio: $PSRR = \frac{HistoricalInstalledServerBase}{PostVirtualizatinInstalledServerBase}$
- Power Usage Effectiveness: $PUE = \frac{TotalFacilityPower}{ITEquipmentPower}$
- Data Center infrastructure Efficiency: $DCiE = \frac{1}{PUE} = \frac{ITEquipmentPower}{TotalFacilityPower}$
- DR = Whole Building Power (total w, % w, etc.)

Results: DR Strategies

Data Center Infrastructure	DR Strategy	Advantages	Cautions[1]
	1.Adjust supply-air temperature and/or humidity set-points to industry and ASHRAE ranges (recommended or allowable): a.Adjust data center zone supply-air temperature and humidity set-points. b.Adjust HVAC temperature set-point for mixed-use data center zones.	▪Sequence of operation for this strategy is well studied and implemented in offices and commercial buildings. ▪Strategy could be part of control system sequence of operation.	▪Not applicable to data centers already operating at higher temperatures. ▪Airflow management issues. ▪Perceived risk of IT equipment failure if strict environmental conditions not maintained.
	1.Use innovative cooling system management: a.Shut down redundant chillers, pumps, and CRAC units in response to IT equipment needs. b.Expand outside-air temperature range for economization (water or air).	▪Significant savings when used with IT infrastructure strategies.	▪Higher outside air wet-bulb temperature may raise cooling water temperature. ▪Weather dependence of air or water-side economization. ▪Research concept for DR.
Site Infrastructure and Mixed-use			
	1.Use lighting controls: a.Use bi-level switching or dimmable lighting controls to reduce lighting levels.	▪Sequence of operation for this strategy well-studied and implemented in office spaces and commercial buildings. ▪Lights could be shut down completely.	▪Minimal impact as stand-alone strategy in non-mixed-use data centers.
	1.Reconfigure redundant power delivery and back-up storage systems: a.Use UPS bypass technology. b.Shut down redundant transformers. c. Use back-up storage.	▪Strategy for shorter duration ▪Back-up storage in use outside California; system testing can coincide with DR event.	▪Perceived impact on equipment or risk of error or malfunction (a). ▪Perceived need for additional back-up storage during DR (c). ▪Potential for air-quality issues if diesel generators are used (c). ▪Research concept for DR (a & b).

[1] "Research concept" in this column indicates that this DR strategy is still under development, and the impact on energy savings and scalability needs to be quantified.

Results: DR Strategies

Data Center Infrastructure	DR Strategy	Advantages	Cautions[1]
	1. Use virtualization technologies: a.Increase server processor utilization rate and consolidate. b.Increase storage density and consolidate. c.Improve networked device efficiency.	▪Enabling technology available (a & b). ▪Enabling technology maturing (c).	▪Increased utilization rates for servers may increase cooling needs with overall efficiency (a). ▪Research concept for DR (b & c).
IT Infrastructure	**1. Shift or Queue IT or back-up job processing**	▪Enabling technology in use. ▪Could be used as load shift.	▪Suited for laboratory or research and development data centers. ▪Research concept for DR.
	1. Use built-in equipment power management	▪Built-in power management present in most equipment already. ▪Energy savings higher in newer systems.	▪Minimal energy savings for most current equipment. ▪Needs to be combined with virtualization and load shifting of IT or back-up job strategies for DR impact. ▪Research concept for DR.
	1. Use emerging load migration technologies for shed or shift	▪Enabling technology available for some. ▪Perennial strategy ("anytime DR").	▪Infrastructure available in only a few data centers and used primarily for disaster recovery. ▪May need local utility coordination. ▪Research concept for DR.
IT and Site Infrastructure Synergy	1. **Integrate virtualization, HVAC, lighting controls, etc. for faster load-shed response**	▪These intelligent strategies have higher potential energy savings than stand-alone strategies.	▪No enabling technologies available currently. ▪IT and site infrastructure technology and performance measurement currently separate. ▪Research concept for DR.

[1] "Research concept" in this column indicates that this DR strategy is still under development, and the impact on energy savings and scalability needs to be quantified.

Example: Analysis of Strategies

Work Load Migration	Data centers with fully networked infrastructure within different electrical grids, zones, or geographic locations, can shift loads temporarily to other locations in response to a DR event.
Applicability	IT and Site Infrastructure
End-Use type	Server, storage, and networking devices
Target loads	Potentially all loads
Category	Load shed
Development Status	Research
Summary of Potential Strategy	**Temporarily shift IT load to redundant networked location:** ▪ Use fully remote networked redundant infrastructure and automation capabilities to selectively or completely shift IT equipment load in response to a DR event. This percent of IT load migration is referred to as LM_{it}%. ▪ Unused IT equipment could be shut down. ▪ A percentage of the load of supporting site infrastructure services could be minimized. The percent of site load migration is referred to as LM_{st}%. ▪ The resulting lowered energy use could be significant.
Rebound	Rebound avoidance strategy required to restore local operations.
Caution	Emerging technology. Used primarily for disaster recovery. Advance notification and coordination among local utilities may be required. Impact on energy savings and scalability needs to be quantified.

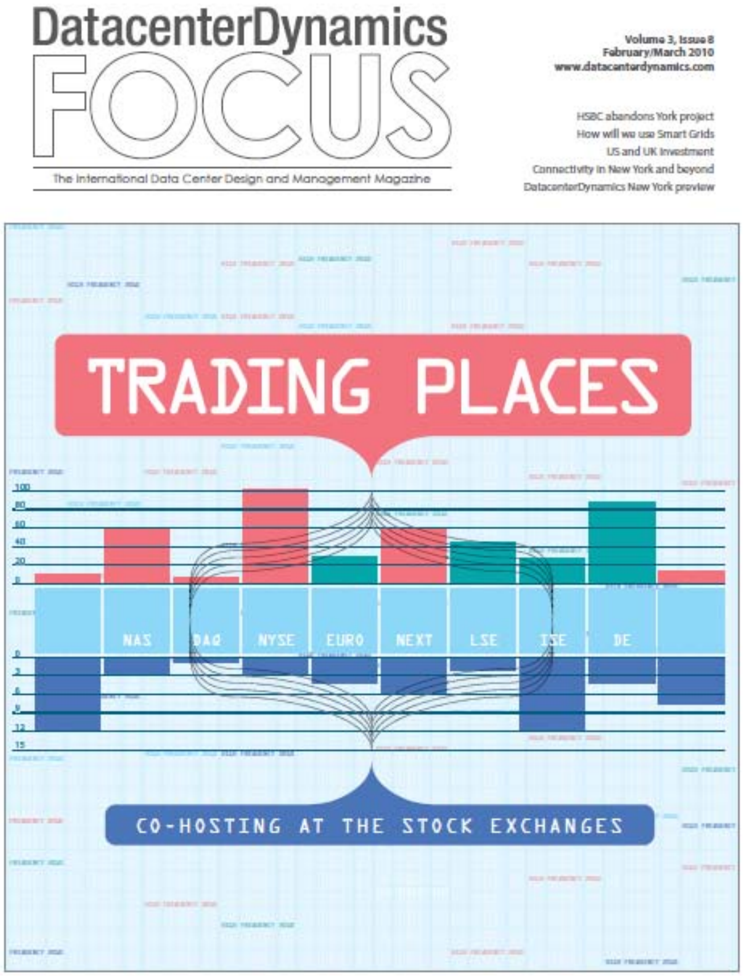
- Anytime DR Strategy… follow the Cloud!

Data Center Challenges/Potential Solutions

What's necessary before strategies are considered?

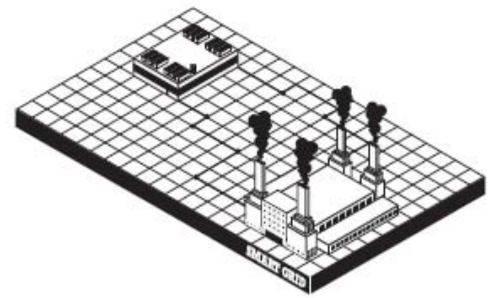
- Parallels to EE few years ago
  - Demonstrations and field tests
- Perception of risk to business and operations.
  - R&D data centers.
- Performance measurement strategies/metrics.
  - Simplified for DR
- Lack of Information.
  - Education and outreach.

Data Centers and Smart Grid/ DR



IS THE SMART GRID AN INTELLIGENT MOVE?

Does the smart grid have a role to play in the future of data centers? By Yevgeniy Sverdlik



The system of power delivery in the US is in trouble – it is old and creaking. To prevent more gigantic financial losses similar to the ones the US economy has already experienced as a result of blackouts, the government is looking to change the way in which the grid is designed and operated.

The US Department of Energy (DoE) is investing in the research and development of the 'smart grid'. It defines two main stages in this theoretical development process: a smart grid and a smarter grid.

A smart grid is the vision of a more removed future, according to the DoE's 2008 paper on the subject, *The Smart Grid: An Introduction*: "The longer-term promise of a grid remarkable in its intelligence and impressive in its scope."

A smarter grid is one that can be built using technology that is available today, or that will become available in the near future.

Today's grid, according to the DoE, is characterised by uninformed consumers, dominance of central generation, limited wholesale markets, slow response to power quality issues, poor integration of operational data with asset management, and vulnerability to "malicious acts of terror and natural disasters".

The DoE's vision of the smart grid is that of a system whose consumers are involved and active – one that leverages demand response and distributed energy sources. A smart grid has many distributed energy sources, with focus on renewable energy. The future system is one that is resilient to attacks and natural disasters, and where power quality is a priority.

According to the DoE paper, growth in peak demand for electricity in the US has exceeded growth in transmission by 25% annually since 1982. Lack of sufficient investment into transmission and distribution infrastructure in the country has compromised the grid's efficiency and reliability.

The US economy has already paid dearly for the lacklustre state of the nation's electrical infrastructure. According to the DoE, a rolling blackout across Silicon Valley resulted in losses that totalled $75m. A one-hour outage at the Chicago Board of Trade in 2000 caused a delay in trades that were cumulatively worth about $20 trillion.

The 2003 blackout in the northeast (the largest in US history) caused about $6bn in economic losses to the region.

Theoretically, a smart grid is intelligent enough to sense and predict overloads and reroute power to avoid such outages or minimise their impact.

SMART BUILDINGS

An essential component of a smart grid is a smart consumer: a smart building. Data centers are some of the most intelligent buildings built. To GE's Marcel Van Helten, the strong relationship between the smart grid and the data center is a no-brainer.

"It is an interesting combination that absolutely makes sense," says Van Helten, infrastructure market director for GE Intelligent Platforms.

Van Helten sees three ways in which data centers relate to the smart grid: as consumers, as contributors and as enablers, although the first two, in a way, fold into the third.

"A data center is a load on the smart grid," says Van Helten. "What a smart grid wants to do is be more flexible for producers and consumers to better balance the electricity supply chain."

PEAK DEMAND

When a smart grid is at peak demand and needs to shed load, it can send a signal to some of its largest consumers to come off the grid fully or partially to reduce their consumption. A typical data center is already designed to be able to run independently of the utility feed for a prolonged period of time, and there is usually a largely automated process in place to make the transition quickly.

In Van Helten's opinion, convincing data center operators to work with their electricity providers in such a way would take incentivising them with lower rates. "For the data center, the energy is a huge cost factor. I would imagine that, in the spirit of making more money, they would actually make that decision."

Participation in a smart grid would also make a good component for a company's sustainability programme – something more and more organisations are concerned with.

"Data center operators are interested in being sustainable," Van Helten says. "They know they're a major energy consumer and they're looking at ways to reduce that."

Besides easing demand on the grid, data

Cloud Computing and Data Center DR

CLOUD INFRASTRUCTURE KEY ENABLER OF DATA CENTER DEMAND RESPONSE

Few companies have the appropriate power infrastructure and 'smart grid' still has a long way to go

The case most often made for cloud computing is that it increases efficiency of the way companies consume IT services, enabling them to reduce cost. A group of scientists in California suggests that big companies with extensive geographically dispersed data center topologies that act as private clouds should also use these capabilities to participate in demand response, which will help reduce cost further and more.

Organizations that leverage their clouds to shed load when grid operators ask them to will make substantial contributions to efforts to lower strain on power grids that serve their data centers and other businesses and residents in their regions. A cloud-like infrastructure is key. This is suggested by the latest study on demand-response opportunities for data centers conducted by the Department of Energy's Lawrence Berkeley National Laboratory in California, in collaboration with K.C. Mares of Megawatt Consulting and David Shroyer of Shroyer Consulting Group. One of the study's conclusions is that virtualization – prerequisite of the cloud delivery model – is the biggest opportunity for demand response in data centers, providing the ability to reduce both IT and cooling power loads.

The idea is simple: when one data center receives a message from operator of the electrical grid it is connected to that load on that grid is high at the moment, the data center drops its electricity consumption by transferring a portion of compute workloads it is performing to a facility in a different location, where load on the local grid is lower. According to Girish Ghatikar, business and systems analyst at LBNL who headed the team behind the study, said some data centers already have the infrastructure necessary to implement such a strategy. Today, these capabilities are primarily used for disaster-recovery purposes and to cut cost. While implementation of demand-response strategies will cut cost further (power is more expensive at peak demand), all users also have the responsibility to do their part in prevention of brownouts and blackouts, in Ghatikar's opinion.

EXISTING OBSTACLES

Main obstacles to a widespread implementation of such strategies today are the fact that very few companies have the infrastructure necessary to shift loads in this way and the fact that few utilities offer real-time pricing for energy at retail level – a common practice in the wholesale electricity market.

Successful implementation of demand response by data centers on a large scale would also require comprehensive real-time assessment of power availability in various geographic regions and demand response that is coordinated among all users and power distribution grids involved. Such a level of coordination is needed in order to avoid destabilizing portions of the grid that load is shifted to. One argument against investing into smart grid and focusing more on on-site co-generation is that electrical infrastructure in the US is old and overloaded. In Ghatikar's opinion, successful coordinated demand-response events can help reduce strain on the grid and reduce additional investment of public funds into building out more electrical infrastructure.

DATA CENTER INFRASTRUCTURE PREREQUISITES

In addition to a smart grid outside the data center, the mission-critical facility capable of working with the grid to balance out demand has a set of necessary characteristics.

First one, as already mentioned, is a cloud-like IT service delivery, where the infrastructure is shared by applications neither of which is reliant on one particular set of hardware to perform adequately.

This delivery model requires advanced servers that are easily susceptible to virtualization and that can either reduce power consumption as their compute load drops or quickly switch themselves off or go to a low-power mode when idle and then, just as quickly, get back up to normal processing capacity when needed.

One reference LBNL makes is to a 2008 proof-of-concept project conducted by the storage vendor NetApp at one of its data centers to study consolidation by virtualization. While keeping details of the study private, NetApp concluded that servers can potentially be idle for up to 26 percent of the time. Another conclusion was that virtualization policies could be used for "graceful power-on and power-off."

Also critical to demand response by compute-load shifting is extremely robust network infrastructure that connects the data centers involved, as the strategy would enjoy very little popularity if shifting compute loads between sites was not seamless. Such network infrastructure is not yet available in the US at mass scale.

Finally, automation is crucial in the process. "You can't do this manually," Ghatikar said. "No way. You need to have an intelligent technology infrastructure to be able to do that."

DEMAND RESPONSE POSSIBLE TODAY

Even though there are still significant barriers to successful wide-scale demand-response participation, select companies can and do participate in demand-response events even today. Utilities, like PG&E in California, offer advanced notification for such events and companies, if they so desire, can prepare to shift their compute loads when such events are scheduled to happen.

When designing a system that will allow them to participate in demand-response events, Ghatikar recommends that companies consider two dimensions: depth (how many hours can they drop the load for at a particular location?) and breadth (how many kilowatts they can drop load by?). "Those are the things that will help you to build the platform to be able to participate."

Value Proposition for Data Centers

- Emerging Value Proposition: savings for time scales of energy value chain.
- DR participation in multiple electricity markets, retail, wholesale, forward capacity markets
- Utility retail DR and Smart Grid programs
  - Auto-DR programs/incentives (http://www.auto-dr.com/).
  - ARRA demonstrations
- Corporate and Social Responsibility: Societal benefits
- Potential CA study (Phase 2) project: Field tests.

Industrial Controls/IT Systems Assessment Survey

- We need to better understand the existing technical potential for Auto-DR.
  - Technical and operational capacity.
  - Need data center community voice.

Contact

- Demos/survey/program opportunities:
  - Rish Ghatikar
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    - http://drrc.lbl.gov/industrial/