Smart Loads and Smart Grids—Creating the Smart Grid Business Case

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Abstract

While the core operations of the grid attract the most smart grid attention, the most important smart interactions will come from the grid's end nodes which include industrial facilities, commercial buildings and homes. The end nodes do not have the constraints on technological risk and on diversity that the core grid does. Individual owners and operators can make their own decisions. Approaches that maximize incentives for technology adoption in and wide participation of the end nodes will likely best accelerate smart grid deployments.

This paper draws on best practices in software integration, applying the literature on barriers to value creation, and discusses common approaches in energy integration today and tomorrow.

1. INTRODUCTION

Traditional business models have discouraged end node participation. Utilities have provided both price and risk arbitrage to the end nodes. This double arbitrage has reduced end-node interest in working with the grid, and reduced consumer propensity to offer premium prices to different power generators.

Today, grid operating margins are slim and volatile energy sources provide a growing portion of the grid's power. The need for and benefits from end node participation in matching energy supply and demand will only grow in the future.

Current practices to balance energy supply and demand are difficult and intrusive. They are complex because they rely on direct management of systems within the end nodes that serve diverse purposes and use many technologies. They are intrusive, because they use un-invited remote control to change conditions in customer homes and businesses. They are often ineffective, because they manage efforts rather than results.

To limit diversity and intrusiveness, grid operators have committed to minimal response—and minimal benefits.

Each end node is a microgrid, supporting multiple systems that provide multiple services to its owners and occupants. A growing number of these microgrids include services for energy generation and storage as well. These operators of these microgrids, homeowners and businesses, are better positioned to optimize benefits and energy use within the end nodes than any remote operator can be. We call these self-optimizing end nodes "smart load"

2. THE PROBLEM OF ENGAGEMENT

If a grid is not transactive, it's not a smart grid.[1] With these provocative words, Dr. Kiesling addresses the fundamental issue of engaging the end nodes in balancing energy supply and demand, as well as the similar problems of site-based storage and site-based generation. Smart energy requires the balancing of energy supply and demand.

2.1. Consumer avoidance of risk

Every decision is an assumption of risk. Traditional markets in electricity have been designed to manage risk for the consumer and, to the extent practicable, to eliminate it. Fixed prices set by public commissions limit price risk. Reliability risk has been managed by centralized base-load generation with little regard for over-supply. Arbitrage of risk has always been a significant, if tacit, component of the offerings of the traditional utility business model.

This model is already breaking down, as shown by the increasing interest in Demand Response (DR). Current U.S. public policy will make this problem worse. Any significant inclusions of renewable and un-reliable energy sources will increase the volatility of energy supply on the grid; the problem of aligning supply and demand will grow worse.

Consumers must be encouraged to participate in energy decisions. This can only be seen as an increase in consumer risk. Such assumption risk can either be mandated, or it can be bought. Only the latter will encourage the development of new technologies and new approaches.

2.2. Growing diversity of market interactions

Traditionally, the grid has been seen as the source of all energy. End nodes have been seen as pure consumers of energy. When we use the term end nodes in this paper, we mean anything attached to the grid which is not the grid, and which is not a bulk generator. End nodes have traditionally been classified as Residential, Commercial Buildings, and Industrial Sites.

These simple classifications will no longer suffice. Any definition of end nodes will have to include micro-grids. Plug-in electric vehicles (PEVs) are a significant new component of load with variable demands and roaming location. Site-based generation and storage add another novel addition.

These new actors cannot be managed as they have been. By their nature, they require at least some local intelligence and control.

3. THREE PATHS TO BALANCING ENERGY

There are three paths to balancing energy supply and demand. Energy generation and distribution can be tuned to be highly reactive to demand. Utilities can directly manage energy use in the end nodes. End nodes can become autonomous and manage their own alignment with supply.

3.1. Dynamic balancing of energy supply

Dynamic balancing of energy supply requires anticipation of the needs of the end node and rapid dispatch of generation to support it. Aside from hydro power (and the closely-related pump storage), there are few generation options that can respond quickly and with minimal expense.

Traditional base generation, such as nuclear or coal, does not respond quickly enough for load-side balancing.

Today's systems for supply-side balancing are too expensive, in money and in fuel, for the more dynamic grid going forward. Near line systems expend fuel to be ready to generate at a moment's notice. Fast-start gas generators burn immense amounts of fuel during start-up. Relying on these near-line technologies for any significant portion of the net load may well be more expensive, in carbon, cost, and fuel, than the benefits of alternative energy generation. [1]

It is national energy policy to introduce increasing amounts of renewable energy generation into the grid. Many of the processes rely on unpredictable or unreliable, sources. Sun, winds and tides are unpredictable, intermittent, or cyclical at best. These energy sources create increasingly volatile electricity supplies.

Supply-side energy balancing will not work in the future without prohibitive costs.

3.2. Managed Energy

In recent years, utilities have come to rely upon direct management and control of systems inside the end nodes, often called Direct Load Control (DLC). This has been tolerated by the end nodes only because it is rare.

The issue of transferred costs is always present—turning off air conditioning compressors at certain points in their cycles reduces life; likewise drawing from vehicle batteries reduces battery life. The cost is born by the managed facility but is seldom fully visible.

Managed energy goes by many names, including ZigBee Smart Energy Profile (SEP) [4] and [Requirements for] Open Home Area Networks (OpenHAN). [5] The advantage of managed energy is that it requires no engagement of the end node. It requires minimal equipment expenditure inside the end node. Managed energy is applied most successfully today in homes, where the diversity is limited. Many managed energy events in homes occur when the residents are not there.

3.2.1. Managed Energy in Residences

Managed energy in residences is always restricted to minimal response. Consumers do not like relinquishing control over the internal operation of their homes to outsiders. Each DR event under managed energy appears as an uninvited intrusion into the home. Consumers consent to only minimal response because they are not engaged.

3.2.2. Managed Energy in Commercial Buildings

Most DR in Commercial Buildings is applied using managed energy principles. Commercial buildings are more complex than residences, and so are less well understood by outsiders, including utilities. This means it is easier for the facility operator to game managed energy in commercial buildings.

Commercial operators have been known to sign agreements to turn off the central chiller for a demand event, and to use

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[1] It is well known that the cost of balancing wind energy, particularly with gas turbines, is high. See e.g. [2] and [3].

their in-place building control systems to turn on window AC units with the same signal. Such a response follows the letter of the contract, but in fact increases building energy load during a DR event.

3.2.3. Managed Energy in Industry

Managed energy is rarely used in industrial settings because the costs of interrupting long running high-energy-requirement processes can far exceed the cost of the energy. Managed energy can be used in a limited way in the office and warehouse portions of industry; such use is more akin to applying managed energy to a commercial building in the midst of an industrial site.

3.2.4. Summary of Managed Energy

Managed energy appears the easiest to apply as it is a direct extension of approaches used to manage the grid itself. Consumers have no strong buy-in to managed energy, and so will try to limit its application, even where it is mandated.

Because managed energy uses deep process oriented integration across boundaries of ownership and purpose, it cannot guarantee results. The balance of superior knowledge and control will always be held by the occupant of the end node; the supplier is always negotiating from a position of weakness. Managed energy requires no buy-in or engagement from the end node. This leads to gaming of managed energy whenever the occupant of the end node can achieve advantage or minimize discomfort.

3.3. Collaborative Energy

Collaborative energy relies on light coupling of systems with response urgency dictated by economic signals. Consumers are able to respond as little or as aggressively as they want. “Every brown-out is a pricing failure.”[6]

Because collaborative energy requires no detailed knowledge of the internal systems of the end nodes, it is indifferent to stresses caused by changes in technology within the end node, and is more accepting of rapid innovation

Because collaborative energy offers economic rewards without loss of autonomy, end nodes may seek to maximize their economic opportunities. Collaborative energy creates a market for end-node based technologies to save, store, or generate electricity on demand.

Collaborative energy signals are results oriented signals and are agnostic about technology. Light, loose integrations based on service–oriented signals adopt enterprise best practices.

3.3.1. Collaborative Energy in Residences

It is a long-held dictum that residences were unable to participate effectively in price-based demand response. The ground-breaking Olympic Peninsula Project [7] disproved that assumption, as homeowners were able to better reduce energy usage and respond to local congestion when responding to price signals than were homes under managed energy.

The Olympic Peninsula Project was distinguished from a traditional managed energy project by its smart thermostat and meter. Direct control of building systems using managed energy approaches were transferred from the managing utility to the thermostat. Price signals and an innovative user interface then transferred autonomy and decision-making to the home owner.

3.3.2. Collaborative Energy in Commercial Buildings

Larger commercial buildings have long had the intelligent infrastructure necessary for collaborative energy. Large buildings have custom control systems, often based on PCs.

The same features that make commercial buildings poor participants in managed energy (see above) make them ideal candidates for collaborative energy.

The growth of collaborative energy in commercial buildings has long been stymied by the reluctance of energy suppliers to share live usage and price information. This limits the ability of commercial buildings to understand their own energy use, and thereby to make commitments to changing energy use. Shadow meters are expensive, and are a duplicative capital cost.

3.3.3. Collaborative Energy in Industry

It is often expensive for an industrial site to curtail significant load on short notice. Industrial processes are characterized by long run times and large, if predictable, energy use. Industrial sites are not a primary focus of DR.

Industrial sites do have three means of participating in collaborative energy. (1) They can schedule those long running processes in advance. (2) Because of their scale, industrial sites can manage the shape of their load, balancing internal processes. (3) Industrial sites are often supported by combined heat and power plants that can be assets to a stressed grid.

Collaborative energy scheduling in industrial sites requires that the plant operators know the energy profile of long-running processes. The site operators can then request bids that energy profile on various schedules. Using price signals, the supplier can influence when those processes occur. This allows large-scale load shifting and improves the suppliers’ ability to estimate loads.

Within a large facility, there may be many motors, and many different environmental systems. Such loads are episodic, using lot so energy when running, and none when they are not. Large energy consumers are often charged for peak load, as well as for overall energy use. Operators can coordinate systems so that energy spikes from different systems do not coincide.

This sort of load shaping becomes more important as the operating safety margins of the grid become less. While load shaping may cause some inconvenience at any time, it is much more valuable to supplier during peak energy events on the grid. Differential pricing by time or dynamic pricing for load spikes as well as overall load size can aid in grid stability. Time differential pricing of usage spikes can also encourage shifting of overall load, as the convenience of day-time operations is offset by the convenience ignoring load shaping.

Generation that produces multiple usable energy streams is referred to as cogeneration. Combined heat and power, wherein a facility produces electricity and steam is the most common kind of cogeneration. A cogeneration facility can often, within limits, vary the output of thermal and electrical energy. Because it usually has a distribution system for thermal energy, it has the means to store thermal mass. Economic incentives through collaborative energy give industrial sites the incentives to further develop these capabilities.

3.3.4. Summary of Collaborative Energy

Collaborative energy relies on intelligence in each end node of the grid. That intelligence is embedded in systems that understand the particular features of each end node better than a central supplier ever will. In particular, systems in the end node will better understand the business processes and aspirations of the occupants of that end node than will the grid.

Collaborative energy response by each end node will be more variable than is managed energy. An end node may decide whether or not to participate in any event. The end node may also choose to participate more fully, as an autonomic decision, in a particular DR event.

If price and risk arbitrage, coupled with obscure regulated accounting, are barriers to the smart grid, the generative solution includes shared honest, transparent accounting and limiting the interoperation points and complexity for the smart grid. In other words, we need to treat energy markets more like we treat financial markets.

Under collaborative energy, service performance matters more than process performance. This reduces the complexity required at the grid level to manage distributed energy resources (DER). Both generation and drain-down of storage may be indistinguishable from demand response. Battery filling is just one more service responding the cheap energy.

4. SERVICE ORIENTED ENERGY – SERVICE ORIENTED BUILDINGS

Light coupling, loose integration and service orientation are best practices in enterprise integration. This section is adapted from a paper by Considine. [8]

4.1. Light Coupling and Loose Integration

Loose integration describes an integration approach in which interoperation points exchange only the minimal information needed to dispatch requests across the interface. The primary advantage of loose integration is its simplicity and flexibility. The simple interface is easier and faster to specify

Because loose integrations eschew specification of non-essential details, they are more likely to be reusable when interacting with a different technical partner. Loose integration supports diversity of partner. This tolerance of diversity makes adapting to innovations easier and less expensive.

4.2. Service Orientation

Service orientation [9] refers to an integration approach that focuses on the desired results rather than the requested processes. Service orientation complements loose integration. Service orientation organizes distributed capabilities that may be in different ownership domains.

Visibility, interaction, and effect are key concepts for describing the SOA paradigm. Visibility refers to the capacity for those with needs and those with capabilities to be able to see each other. Interaction is the activity of using a capability. A service provides a decision point for any policies and contracts without delving into the process on either side of the interface,

Services are concerned with the public actions of each interoperating system. Private actions, e.g., those on either side of the interface, are considered inherently unknowable by other parties. A service can be used without needing to know all the details of its implementation. And services are generally paid for results, not effort.

4.3. Service Oriented Energy

Applying the principles of service oriented architecture to energy use promotes much-needed innovation while reducing complexity. At each point, transactions are based upon delivery of a service: reliable energy, verifiable demand-response, predictable loads.

The service orientation paradigm hides internal processes. Any technology that stores energy is equivalent. One customer changes the ambient temperature, the other sits in the dark; both offer the same demand response to the grid.

Because service offerings are concerned only with results, response verification, which today can take 60 days or more, becomes simple. Verification is seen in the results shown by the meter. In any system, stimulus creates the greatest response when stimulus and response are proximate. Service oriented energy will increase demand response by eliminating verification delays.

4.4. Service oriented buildings

Buildings are prevented from full participation in smart grid markets by a process orientation. If it is too hard to tell what effect a response will have on the building occupants, the operators of that building will work to minimize response.

Businesses minimize risk. Landlords minimize risk to their revenue stream, which comes from happy tenants. A landlord might earn a small reward from the energy supplier for a certain change in operations. If that change annoys his tenants, .then he may see lower occupancy rates in the future. This not only reduces the direct revenue stream, it reduces the re-sale value of the building by reducing the all important ratio of revenue to capital cost (“Cap Rate”). Unless the reward is great, it is safer to avoid making a demand response decision.

As building systems get defined and managed in terms of the services they provide, and the cost of those services is expressed in energy use, things change. The building operator can evaluate demand response strategies in terms of degradation of specific services in use by specific tenants at specific times. This service oriented perception on building systems reduces risk by increasing certainty. The owner is able to tolerate greater demand-response.

As buildings become managed more like microgrids, they accrue energy generating and energy storage services along with the energy using services. The overall energy posture of a building can be managed internally using service oriented principles. This approach allows for the more rapid introduction of new technologies into the building. The service oriented building is ready for energy innovation.

The better a building manages its internal services, the better asset it is to the grid. Reduce consumption, increased internal generation, and reliance on stored energy all produce the same effect on current energy required from the grid.

As landlords experiment with visible managed tenant services, new concepts such as green leases become ore viable. The service descriptions that increase situation awareness for the landlord can also increase awareness by the tenant.

Buildings are only a responsive asset to the grid to the extent that they have control over their own operations. Service orientation inside the building can bring a building into control for both the landlord and the tenant. The landlord and the tenant can work together to balance energy use with external economic signals.

5. TRANSACTIONAL ENERGY

Services require abstractions. The fundamental transaction of the smart grid is the acquisition of energy at a point in time. The value of that energy changes over time because of changes in supply and changes in value (demand).

The common abstraction for supply, demand, and scarcity and value is money. For a commodity, it may be the only abstraction that matters. The signals between the services must be primarily economic.

Economic signals are light and loose; economic signals exchange only the minimal information of supply, scarcity, and value. Service economies pay for results rather than for efforts; transactional energy is service oriented.

The OASIS Energy Market Information Exchange Technical Committee [10] is working to define the form and nature of economic information exchanges. See also Cox and Considine’s paper in this conference. [11]

5.1. Barriers to Transactional Energy

Transactional energy relies on clear, clean signals that can be easily understood. Because most energy transactions are small, they must be automatable to achieve full participation. Anything that muddies the economic signals is a barrier to transactional energy.

Price and risk arbitrage, traditional services provided by utilities, muddle economic signals. By dulling the signal, they lessen the response.

Using tariffs instead of prices decreases the transparency of message needed for smart grid interactions. Suppliers who wish to make service-supporting systems need national markets over which to amortize their development costs. Tariffs are inherently local. If a tariff is used to generate a price, that generation is an internal and inherently occult process. Service interfaces should always express the results of those tariffs as simple prices.

6. LOAD SHAPING AS FUTURE READINESS

It is easy to focus on smart load, demand response, and load shaping as technologies in service to the grid. Such assumptions make the managed energy approach seem natural and safe. Autonomous systems able to manage their load, curtail their response, and shape their load offer benefits to other business models as well.

A well behaved and more predictable load is a more valuable load.

6.1. Dis-Integration of the End Nodes

Control systems in the end nodes face, particularly in Industry and in Large Commercial, face problems analogous to those in the grid.

These systems are often over-integrated to compensate for the lack of an over-arching architecture. After integration into monolithic systems, they offer few entry points for interactions with building occupants and their systems. It is difficult and expensive to make partial upgrades to these systems because of the difficult and time consuming integrations needed to bring new components into the old integrated console.

Models of service oriented energy use in the end nodes make just as much sense for decoupling systems within a building. Abstract interfaces enable manage of building services as components. Exposed services can be more easily understood as supporting different business functions, i.e., air handlers for the 1st floor, 2nd floor, and executive suite are more understandable than energy use for the building.

If these systems can express their actual energy use in a way comparable to that provided for the entire building, then the entire building becomes more manageable and responsive.

And that can only improve demand response.

6.2. Autonomous Load Shaping

We have discussed Industrial load shaping above. Autonomous load shaping will find its place in Commercial and Residential spaces as well.

Current conversations among buildings and appliances technologists foresee each system being able to respond by monitoring its own energy use and tasks, and to report its load profile and anticipated energy use to its peers. Buildings systems (and appliances) would spontaneously assemble the load profiles and back-off on their use patterns to create simple loads without spikes.

Today, load spikes for smaller buildings are just noise to the grid. Over a neighborhood, they blend together stochastically. Buildings able to manage their own load shape are a step toward being better able to manage their demand in response to building signals.

More importantly, such buildings are pre-adapted for site-based energy including storage, near-grid and net zero energy scenarios. A building running on local energy resources cannot afford spikes; there is not grid to back-stop its energy needs. The building's energy budget may vary as the sun shines or as the wind blows. A building able to manage its load shape is ready to for distributed energy.

The same principles can be extended within a microgrid, whether it is a campus, and base, or a neighborhood. A well behaved and predictable load is a move valuable load. That value is even greater in the semi-self-sustaining microgrid, such as a green neighborhood or net zero military base.

7. SUMMARY OF THE BUSINESS CASE FOR SMART LOADS

Smart load is a more important component of smart grid than is generally recognized. Even for traditional Demand Response, smart load participating in collaborative energy may offer greater aggregate response while enjoying wider acceptance. Smart load will attract greater engagement from the end nodes.

The price and risk arbitrage traditionally provided by the grid are barriers to engagement

Smart loads require simple clean communications that are results rather than process oriented. Such communications must be primarily economic rather than control oriented.

Simple interactions, based upon light, loose coupling and service oriented interactions offer the simplest approach to engaged end nodes. Such integration will support innovation in processes and technologies without re-casting the interfaces of the smart grid.

Autonomous load shaping may be the critical development of smart load. Autonomous load shaping is valuable not only to smart grids, but to future energy models, including site-based storage and generation. A well behaved and more predictable load is a more valuable load

Biography

William Cox is a leader in commercial and open source software definition, specification, design, and development.

He is active in the NIST Smart Grid interoperability efforts, including the Domain Expert Working Groups. He contributed to the NIST conceptual model, architectural guidelines, and the interim roadmap and framework documents.

Bill is co-chair of the OASIS Energy Interoperation and Energy Market Information Exchange Technical Committees, and an elected member of the OASIS Technical Advisory Board, where he advises the Board and membership of the leading XML and Web services standards organization in the world.

Bill has developed enterprise product architectures for Bell Labs, Unix System Labs, Novell, and BEA, and has done related standards work in OASIS, ebXML, the Java Community Process, Object Management Group, and the IEEE, typically working the boundaries between technology and business requirements.

He earned a Ph.D. and M.S. in Computer Sciences from the University of Wisconsin-Madison.

Toby Considine is a recognized thought leader in applying IT to energy, physical security, and emergency response. He is a frequent conference speaker and provides advice to companies and consortia on new business models and integration strategies.

Toby has been integrating building systems and business processes for longer than he cares to confess. He has supported and managed interfaces to and between buildings, cogeneration plants, substations, chilled water plants, and steam and electrical distribution. This work led to Toby's focus on standards-based enterprise interaction with the engineered systems in buildings.

Toby has been chair of the OASIS oBIX Technical Committee. oBIX is an unencumbered web services standard designed to interface between building systems and e-business. He is an elected member of the OASIS Technical Advisory Board. He is active on the NIST Smart Grid Domain Experts Groups and works to promote applying information technology to buildings with groups such as buildingSmart and FIATECH.

Before coming to the university, Mr. Considine developed enterprise systems for technology companies, apparel companies, manufacturing plants, architectural firms, and media companies old and new. Before that, Toby worked in pharmaceutical research following undergraduate work in developmental neuropharmacology at UNC.

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