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Home Energy Management with or without an Advanced Metering Infrastructure
[Revised Draft • 3322 Words]

Why are electric utilities progressing so slowly on residential demand response as peak demand for electricity continues to grow, creating the very real possibility of a serious crisis? Even for those utilities where demand has slowed owing to the economic downturn need to be ready for the rapid growth that will come when the economy strengthens. The crisis initially will be financial, as utilities purchase more power from the limited supply of producers, paying more for wholesale electricity on the spot market, while being unable to translate those higher prices into correspondingly higher retail rates. If utilities continue to move too slowly, peak demand will exceed total available generating capacity sooner rather than later (as the economy expands, the population grows, and electric vehicles become more common), forcing utilities to either build new power plants, or impose more involuntary load curtailments in the form of rolling brownouts or blackouts.

To help avert these crises, utilities have implemented some demand-side management programs, including demand response (DR) and direct load control (DLC). For large commercial and industrial customers, these programs already exist on a fairly large scale. For residential customers, however, perceived obstacles are keeping DR programs in the pilot phase and preventing widespread implementation. Residential demand response is an ideal application for smart meters on the smart grid, but the requisite advanced metering infrastructure (AMI) is only now being rolled out. What utilities need, therefore, is a way to implement home energy management programs on a widespread basis independently of any AMI deployment plans. Before exploring how this is possible, it is useful to address both the promise of and the perceived obstacles to, residential demand response.

Demand Response—A "Killer Application"

The ability of demand response to avert a crisis is so promising that one member of the U.S. Federal Energy Regulatory Commission identified DR as a "killer application" for the smart grid. The U.S. Energy Information Administration expects electricity generation from traditional power plants to remain constant at about 4 billion gigawatt-hours (GWh) as demand is expected to approach 6 billion GWh by 2030. Making up the difference will require distributed generation, and a mix of demand response and some other measures identified in Figure 1.

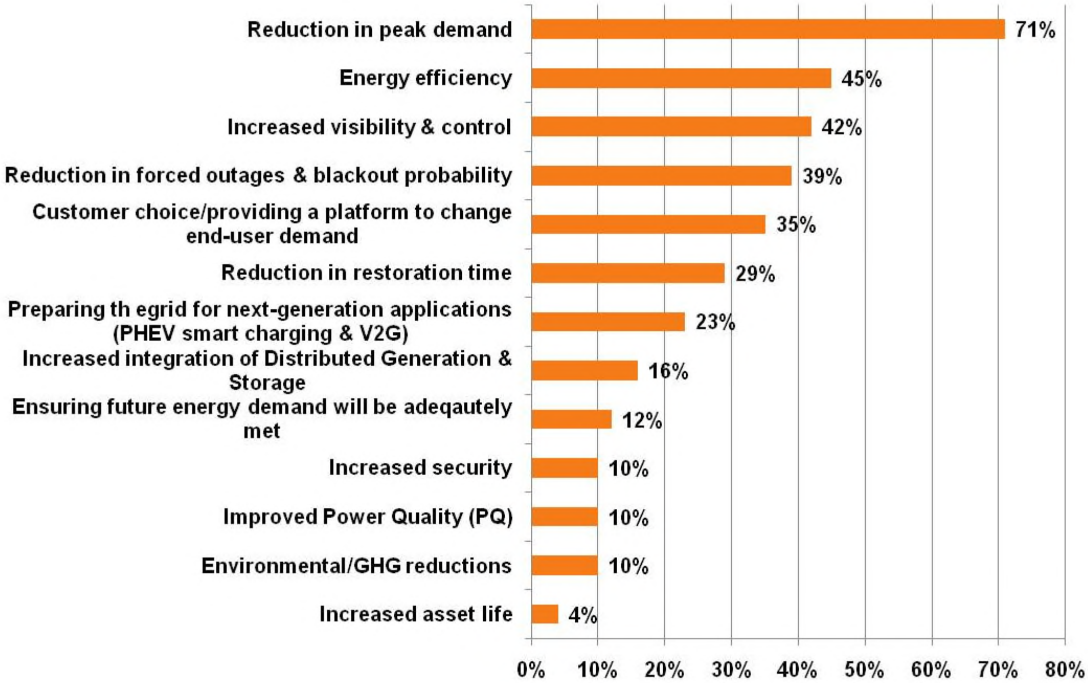

Figure 1: GTM Research asked utilities to cite the top three benefits of implementing smart grid technologies. Shown here are the results, with the "killer application" of a reduction in peak demand ranking first by far.

In the U.S., industrial and large commercial enterprises consume roughly 41% of all electricity generated. This has long been low-hanging fruit for DR because these customers are relatively few in number, and regulators have long supported demand charges for C&I rate payers. Residential and small commercial buildings are not far behind, however, consuming roughly 31% of all electricity generated. Their time for DR has now arrived.

To help lower peak demand in residences, some electric utilities have already implemented DLC for air conditioners and electric water heaters using one-way communications via paging and proprietary radio systems, but most residential price-based and voluntary DR programs are currently only in the pilot stage. The reluctance is not for a lack of need or desire for this "killer application"; rather, it is based in a perception by both utilities and their regulators that residential DR is not quite yet ready for "prime time" given a few remaining obstacles that must first be overcome.

Overcoming the Obstacles

While there can be great comfort in the status quo (especially in the distribution portion of the grid that has yet to benefit from some of the technological advances now found in generation and transmission), every one of the perceived obstacles to DR—whether technical or regulatory, or whether involving consumer adoption or utility integration—can now be overcome. This is not to say that the changes will be effortless or painless. For example, because static, non-time-based residential rate structures have long been the norm, the industry has had little experience with time-of-use (TOU, whether dynamically variable or static), critical peak pricing (CPP) and real-time pricing (RTP) rate structures despite the inevitability of such changes to the status quo. The bad news is: Because these new dynamic rate structures are foreign to consumers (and utilities), the industry will not get it right the first time. The good news is: Any "mistake" made in setting dynamic rates initially can easily be remedied later (albeit potentially with some regulators and utility executives experiencing a few battle scars!).

Consumer adoption of any new paradigm takes time. Remember when all gas stations were full service? The change to self-service did not happen overnight. People's awareness of automobile fuel mileage also did not become commonplace until the manufacturers began posting estimated mileage on every new car. And the mileage testing methodology had to be changed a few times to finally get it right.

Consumer acceptance of dynamic pricing and other changes could be an obstacle to widespread adoption and, therefore, an obstacle to success in reducing peak demand. But studies show that the real issue here is consumer education, and rather simple education in the form of effective educational messages that provide meaningful insights into why DR and dynamic pricing are both related and beneficial. The more consumers understand the problem, the more willing they become to participate in the solution. IBM's 2011 Global Utility Consumer Survey found, for example, that respondents who were most knowledgeable about energy issues were 64% more likely to change their usage patterns.

Similar results were revealed in the 2011 Consumer Pulse Survey conducted for the Smart Grid Consumer Collaborative. A full 80% of respondents strongly or somewhat agreed that the smart grid would help them save money, avoid wasting energy, and make the grid more reliable. Perhaps equally surprising is that "political correctness" also ranked quite favorably, with 78% strongly or somewhat agreeing that the smart grid would better protect the environment and help make the U.S. more energy independent. So it should come as no surprise that 75% also now want more control over home energy use and rate/billing choices.

Still not convinced consumers are ready for DR? The 2011 E2 (Energy + Environment) Study by Market Strategies International revealed a rather remarkable result. They categorized respondents into five consumer segments based on their beliefs and preferences: Anything Clean; Ultra Green; Atomic Efficiency; No Nukes; and Carbon is King. The first four segments naturally responded favorably to the question, "Do you support the idea that your electric utility should start now and work quickly to implement Smart Grid technology?" But even a majority of the Carbon is King segment (presumably the least "green" among us) responded favorably!

With a majority of consumers apparently now ready to accept changes in home energy management, what is preventing so many utilities from making progress on this front? Perhaps they perceive yet another obstacle in the maturity of standards needed for home energy management and home area networking. But these too, at least on the other (consumer) side of the meter, are proven in both numerous pilots and some production roll-outs. The critical standard here is the Smart Energy Profile (SEP). Originally created by the ZigBee Alliance as the application-specific upper layers of the ZigBee wireless networking protocol, SEP at its current level of version 1.1 is a mature and robust specification with new (and backwards-compatible) functionality being added regularly. And SEP version 2.0, which supports the Internet Protocol but has yet to receive final ratification, has already been selected by the U.S. National Institute of Standards and Technology for residential demand response in the Smart Grid Interoperability Standards Framework.

SEP 2.0, while still supporting ZigBee, is also network-agnostic, which has earned it additional support from a growing number of other organizations, including the HomePlug Powerline Alliance, HomeGrid Forum, SunSpec Alliance, Wi-Fi Alliance, IPSO Alliance and International Society of Automotive Engineers. This growing ecosystem is working to ensure that utilities can deploy SEP 1.1 today, and then utilize an over-the-air upgrade feature to migrate to SEP 2.0 in the future to take advantage of new capabilities, such as support for charging electric vehicles. Because the upgrade is not necessary to achieve most DR objectives, however, not all utilities will choose to migrate from 1.x to 2.x—at least in the short-term.

The final obstacle to residential DR does indeed present a bit of a problem: the lack of a robust and inexpensive two-way communications system between the utility and the residential customers. The smart grid, with its AMI network, will obviously fulfill this need—but only for (and until) utilities deploying one. What can utilities without an advanced metering infrastructure do to implement a comprehensive residential demand response program? Use the Internet: an existing network that already reaches virtually every home.

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An Alternative to AMI

According to Parks Associates, approximately 45% of all U.S. households will be served by smart meters by the end of 2015. As few as 10% of those meters, however, will be enabled for two-way communications between a home area network (HAN) and the utility's back-end processing system. Other analysts predict more or less smart meter penetration and HAN capabilities, but the result is the same: Effective residential demand response programs require two-way, near-real-time communications to provide system operators with the ability to monitor demand response actions, just as they do with conventional generation.

Fortunately, there already exists a ubiquitous, reliable and secure two-way data communications network suitable for DR that is available in every utility's service area to virtually every home and is already installed in the U.S. in 63% of them: the Internet. The penetration in larger residences with the highest potential return on the DR investment is even greater. And broadband penetration will only continue to increase as digital subscriber line (DSL), cable modem, third- or fourth-generation (3G/4G) cellular communications, and satellite services are expanded, and competition among these alternatives lowers subscription rates.

All that is needed for utilities to take advantage of the Internet is a dedicated gateway, as shown in Figure 2. The gateway provides continuous two-way communications between the utility and the consumer's home energy management system devices, such as a programmable communicating thermostat (PCT) or an in-home display (IHD). The gateway establishes a secure "service entrance" into the home by connecting both to the broadband modem (via Ethernet) and to the ZigBee, Wi-Fi or other HAN. The gateway is configured for secure, encrypted communications between the utility's DR application and the in-premises system, whether a PCT and/or IHD, and if the utility chooses, optional direct load control, enabling these loads to receive dynamic pricing or direct command and control signals.

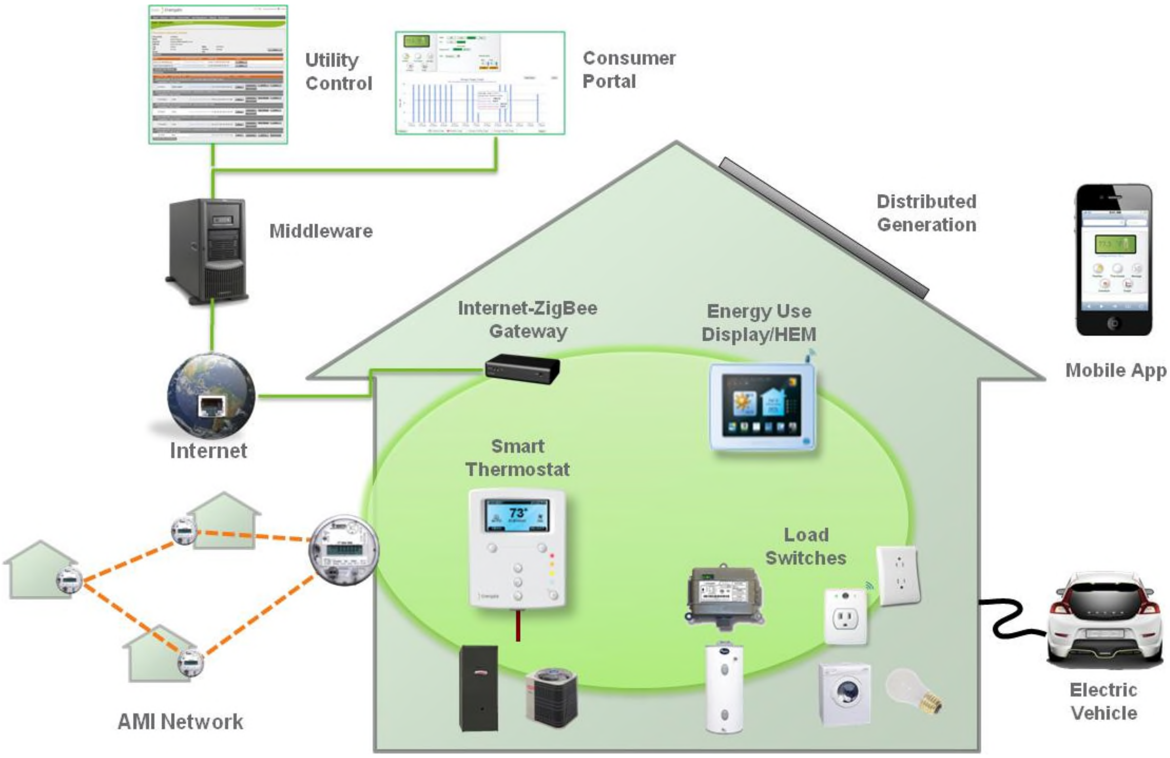

Figure 2: Shown here is a wireless ZigBee HAN served by both a broadband Internet gateway and an AMI network. Note the ability to control other loads, including the charging of electric vehicles, which will be supported in future versions of SEP.

Astute readers may be wondering what happens when a home has both a utility-provided smart meter and a consumer- or utility-provided Internet-HAN gateway? The latest version of SEP 1.1 (technically version 1.1.1) includes a provision for more than one Energy Service Interface (ESI), which is the gateways into the HAN. With SEP, in addition to the gateway function, each network must also have trust center and network coordinator functions; the smart meter (the point of demarcation between the utility and the premises) normally provides all three functions. Support for multiple ESIs enables the trust center function to have different gateways into the same HAN in a secure fashion, thereby changing the HAN from a utility's AMI-limited interface into a robust consumer platform that preserves the integrity of the utility's program while enabling shared control with the consumer. The main advantage for the utility of having an Internet gateway is the ability to implement additional applications, particularly those requiring higher bandwidth than the AMI supports.

Maximizing Customer Buy-in

With ubiquitous two-way communications over the Internet and mature home energy management standards, the only potential obstacle to residential demand response is consumer acceptance. With many consumers now willing to make the change, the real key to broad acceptance is simplicity. Since most consumers continue to have difficulty programming home appliances like microwave ovens and digital video recorders, how can they be expected to make the optimal tradeoffs necessary to balance energy consumption with personal comfort? How many degrees should they raise the thermostat during peak price periods in the summer? Is it safe to temporarily shut off the water heater, refrigerator and/or pool pump, and if so, for how long? What other loads might be shed instead of or in addition to these to achieve greater savings without sacrificing comfort? And how much will that one extra degree of comfort cost?

The best home energy management systems make these and other choices automatically and prudently based on an individual customer's general preference, while also providing a mechanism to help the consumer "tweak" that preference. For example, some customers will opt for maximum cost savings and be willing to tolerate considerable temperature variations, while others would be willing to sacrifice personal comfort for the "political correctness" of reducing their carbon footprint. And while a few will be willing to pay whatever it takes to stay cool and take a hot shower, many if not most will choose a middle ground compromise between comfort and cost. There is no "right" or "wrong" choice, of course, as consumers decide guided by both their wallets and conscious.

The ideal home energy management system would, therefore, operate something like the dial on an old-fashioned thermostat, enabling users to "crank down" the cost or "crank up" the comfort—or chose something in between favoring one or the other. For those consumers who are enthusiastic about home energy management, optional, more in-depth capabilities are already available on some systems. These include, for example: switches and outlets for controlling other loads; opening and closing curtains to increase or reduce solar gain; sophisticated energy management displays, potentially as dockable stations; Web portals showing detailed usage information that provides energy insights; and mobile device applications that enable users to check and change settings while away from home, perhaps from a second or vacation home that also has its own remotely-controllable HEM system.

Operational simplicity combined with good customer communications works. And not just in pilots either. Oklahoma Gas & Electric had such tremendous success with its pilot that the utility is now embarking on large-scale roll-out of almost 40,000 customers by the end of 2012, with more to follow. Pike Research calls OG&E's demand response program "one of the most advanced initiatives in the industry to date" and the firm's forecast of a 38% annual growth in residential DR services over the next five years reveals an expectation that other utilities will shortly be following OG&E's lead.

Protecting the Investment

Utilities choosing not to implement AMI now may still wish to deploy effective DLC programs using paging, FM RDS or even an Internet Gateway. But what happens to the assets used to implement these DLC programs when the utility does ultimately deploys its AMI? With the right solution: nothing. These networks can continue to coexist indefinitely without stranding any assets provided they are properly designed. Existing radio-based DLC programs can continue unaffected, or optionally be transitioned over time to the HEM system by installing a new load switch or upgrading the radio. In situations where two-way HAN communications is built into the smart meter, new residential DR customers will not need a gateway to participate in DR programs. Those who already have a gateway, however, can continue to participate with no changes owing to the multiple ESI capability built into the SEP standard.

While SEP version 1.1 is fully backwards-compatible with SEP version 1.0, this will not be the case with SEP 2.0. Such situations occur often as standards evolve to add more sophisticated capabilities. But the new standard already includes a gateway function that will enable interoperability with SEP 1.x devices, which is all that is needed to avoid stranding assets. In other words: As long as the assets can continue to serve their original purpose, they need not be stranded. Of course, the new, enhanced functionality may not be available for those devices, but they can continue to function as before until being fully depreciated. The key to future-proofing is not from ensuring assets are fully upgradeable, but by ensuring that assets can continue to be useful over their entire economic life. The SEP 2.0 gateway function supporting version 1.x devices is expected to built into future PCTs, IHDs, broadband Internet gateways and potentially other devices, thereby fully protecting all utility (and consumer) investments in existing home energy management technology.

Beyond the investment protection afforded by these provisions in the SEP standards are the many techniques vendors use when designing products to accommodate change. A common one is the ability to update devices with new software, preferably "over-the-air" via the wireless HAN (a capability already specified in SEP version 1.1). Another is a modular design that lets consumers add new capabilities by plugging a new module into an open slot, or by replacing an existing module with a new one. Such "upgrades" can be about as simple as changing the battery or memory card in a digital camera.

Conclusion

The reality is: Utilities and their regulators no longer have any good excuses for postponing residential demand response programs, even on a large-scale. The benefits are clear, and the downside risk can be made minimal—with the right approach. To be sure, there are numerous details to get right. In its Grid Modernization Issues with a Focus on Consumers, the Critical Consumer Issues Forum (sponsored by the Edison Electric Institute) cited 30 such considerations. And the Smart Grid Consumer Collaborative offers additional guidance in its Excellence in Consumer Engagement recommendations. But the other (consumer) side of the meter, whether "smart" or "dumb", is no longer an impediment to progress.

While it is risky to claim any technology is fully "future-proof" with so many advances occurring on so many fronts, home energy management is now about as future-proof as anything can get. The standards are solid and proven in practice. Available solutions are now mature, and most have designs that will survive changes over the foreseeable future. With the consumer side of meter ready to go, the many benefits of residential demand response are now within reach of any electric utility.

Not implementing residential demand response, by contrast, will force utilities to continue to struggle with increasing demand. There will be more stress on an already-overloaded infrastructure. There will be more customer dissatisfaction from rolling brownouts and blackouts. And wholesale power rates will probably increase with little or no means to reflect those fairly on consumers who lack the ability to control their own usage without DR tools.

With comprehensive standards now supporting control of all major residential loads, the worst case scenario for utilities is that some programmable communicating thermostats or in-home displays might need to be replaced at some point in the distant future. So what? Most customers probably remember replacing that old analog thermostat with a programmable digital model they bought at the hardware store, and they will likely understand (with proper education) the need to now replace the digital one with a PCT. And ten or more years from now, after benefiting from smarter home energy management, they may even be eager to replace that (by then) old PCT with a shiny new one offering artificial intelligence or some other must-have feature.

The public seems to understand something many in the electric utility industry often overlook (or consciously ignore): times change. And they are surprisingly (or is it understandably?) willing to change when the gain outweighs the pain. Such is the case today with residential demand response as a "killer application"—with or without AMI.

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