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Touch, Reach, Digitize:

Are utilities looking hard enough at Smart Grid's communications backbone?

By Robert Robinson & Mark Hoffman

Upgrading the U.S. electric power distribution grid is one of the last greenfield technology transformations awaiting our economy, and the ramifications of utility investment that will be required should not be underestimated. Technology innovations in power delivery have been fermenting for years, but only now is the confluence of physical needs and social expectations creating an environment in which real and sustained monetary commitments are being made to create a "Smart Grid," built on information-based devices, digital communication, and advanced analytics.

We believe that the feasibility and merits of a highly integrated Smart Grid are now at hand, and that tangible functionality is available to be deployed in the near term. The issue is no longer whether such a grid can be created, but when it will be implemented and what functionality it will contain.

To achieve the full potential of Smart Grid, a communications network must be in place to allow the existing power distribution grid to monitor and measure usage in real time, visualize network performance, and create an enablement platform that engages everyone from system operators to customers very differently.

One key decision that utilities and regulators now face is to select the backbone digital communications infrastructure that provides the most prudent long-term platform from which to extract end-to-end Smart Grid benefits. No single technology is appropriate for every situation across the U.S. power industry's distribution footprint, but if you envision an end-game that incorporates true nodal digitization of the grid, we believe a compelling case can be made for a communications infrastructure based on Broadband over Power Line (BPL) technology. For utilities that adopt the infrastructure philosophy of ***touch***, ***reach*** and ***digitize***, BPL can provide a sustainable, long-term foundation for differentiated Smart Grid outcomes.

Making a Decision

For utility executives, a technology investment the scope and scale of Smart Grid is daunting. All-in, the cumulative U.S. Smart Grid investment from 2007-2020 is forecasted to be in the range of $70 - 120 Bn, a very wide range highlighting many uncertainties. The risks posed by committing to significant infrastructure additions are very real, and overcoming these risks necessitates broad regulatory and stakeholder engagement. A healthy and open

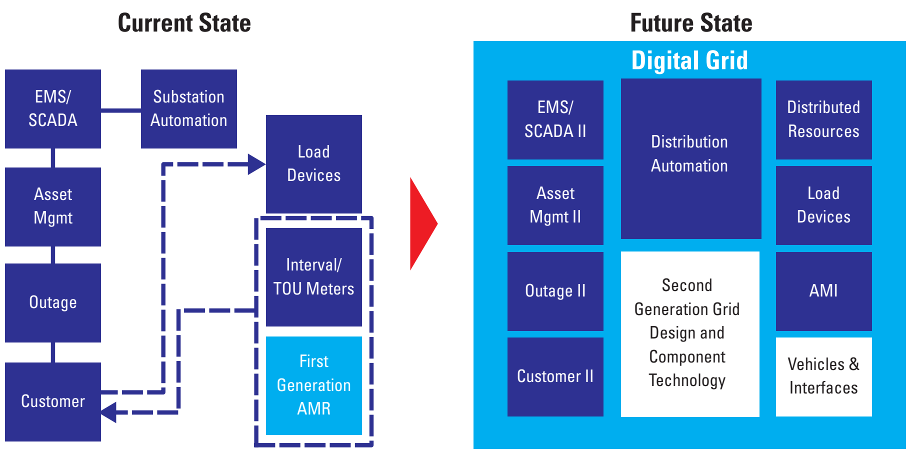

Chart 1

debate on end-game Smart Grid requirements is a must.

For utility regulators, the "bargain" for long-term return-on-investment certainty requires the extraction of full and fair technology potential on behalf of customers, while also allowing the business case for Smart Grid to claim forward social benefits that the utility cannot realistically capture within its regulated cost of service. As regulators decide the merits of grid digitization, they need full visibility into how these backbone decisions might play out.

For many, Smart Grid business cases have been a long time in the making, emanating largely from ~ 15-year efforts to justify the economics of automated meter reading (AMR). While the terminology and technology have evolved, an advanced metering infrastructure (AMI) is still the anchor benefit in virtually all Smart Grid analyses. Digital meter functionality and the associated communications infrastructure to enable it are the largest two investment costs that utilities must recover in rate base.

Broader Smart Grid transformations leverage AMI and seek one or more distribution-centric advancements including grid reliability & security, demand response, distributed energy resource integration, distribution automation, energy efficiency and home automation. These advances trigger some incredibly information-intensive innovations:

- Access to real demand elasticity;
- Automation of grid operations to the point of true self-healing;
- Economic enablement of "beyond the meter" loads and distributed generation resources that will respond intuitively to the grid; and
- Optimization of upstream resources that contribute to energy security, emissions reductions, and power quality.

With the coming information explosion described above, there is no question that utilities and their regulators must vet communications backbone decisions as early as possible in the Smart Grid journey.

Smart Grid Infrastructure

A relatively simple approach to understanding the physical elements involved in digitizing today's electric distribution system is to assess current vs. future state along two dimensions: component functionality and communications infrastructure. As can be seen in

Discrete Digital Grid Functional Capabilities	BPL	Power Line Carrier	Wireless	Telco/Fiber (Off-Grid)
Two Way Communications	4	2	4	4
High-Speed/Low Latency Bandwidth	4	1	4	4
Distributed Real-Time Processing	4	1	3	2
Object/Identity Integration	4	3	3	2
Physical Device Interfacing	3	3	2	1
End-To-End Network Security	3	3	3	2
Network Optionality	4	2	3	0
Customer Optionality	4	0	2	4

No Capability		Partial Capability		Full Capability
0	1	2	3	4

Chart 2

the frameworks (see chart 1 and below), we have stacked component functionality into three columns:

- Head-End Systems – integrated applications that can directly aggregate, assess, and manage the physical, commercial and service aspects of the distribution network.
- Physical Network Elements – discrete components that deliver power (i.e. transformers) or that monitor, control and protect these components and circuits.
- Premise Connections – interface points that measure and control both customer power usage and distribution-level power generation or energy storage resources.

Head-end systems that have largely operated with limited or indirect field and customer information will now be expected to filter, absorb and respond to virtually constant feedback. Field and premise devices will seek out ways to interact with both system-wide information and with each other to enhance reliability and extract economic and/or environmental gains based on dynamic decision rules. The value of undertaking these upgrades will be heavily dependent on the increasing potential gained from real-time information sharing.

Implementing Smart Grid requires a ubiquitous communications infrastructure which we call Digital Grid. The real-time nature of grid information will command the best blend of enterprise networking, application integration and Internet Protocol (IP) standardization. The feasibility of a Digital Grid now exists, but the real challenge centers around two of the more subtle aspects of communications infrastructure design: network integration and access/control requirements.

The long-term information integration objectives of Smart Grid, and especially of the underlying Digital Grid communications backbone, cannot be understated. Use of point solutions to capture low-hanging fruit can be attractive in the short-term, but it is our belief that incremental communications infrastructure decision-making will lead to long term sub-optimization of Smart Grid's potential.

Network Architecture Decisions

A number of technologies are now vying for selection as the standard. No single technology can or will dominate the entire end-to-end Digital Grid for a particular utility footprint. The prevalence of existing communications platforms – especially fiber, whether owned by the utility or not – will have a lot to do with how the infrastructure is extended, and these starting points will have a significant and varied impact on the cost to deploy Smart Grid infrastructure.

We believe it is important to focus on two key network integration assumptions:

- To the greatest extent possible, Digital Grid will plug into, and build off of, available and commercially accessible fiber communications. For some utilities, fiber is already present at most substations and also runs along many distribution circuits. No new technologies will likely supplant this starting point advantage, and offer a superior gain for the foreseeable future.
- Despite the increasing prevalence of fiber, under current economics will not support the extension of fiber to reach 100+ million premises (much less 5 to10 times that many sensors, point load devices or distributed resources that will require a communications interface "be-

yond the meter”). Digital Grid must use technologies other than fiber to close this “fiber gap”.

To integrate Smart Grid across head-end systems, the physical network and premise connections, the communications backbone must be as geographically pervasive as the underlying electric grid itself. The availability of second- and third-tier integration benefits will depend in large part on the ability for proximate devices and processors to interact in a distributed, real-time environment. The information backbone enabling Smart Grid must be as reliable and secure as the electrical network itself, and the unique requirements of Smart Grid will require continuous network monitoring to confirm that sensing and control devices remain in full-connectivity status.

There are three technology parameters that we have used to screen and differentiate technology alternatives: Performance, Path and Penetration. In terms of performance, we focus on technologies that can deliver a sufficient mix of bandwidth, interoperability, scalability, and coverage to meet Digital Grid expectations. From a path perspective, we differentiate between communications technologies that go “through the wires”, “near the wires” and “independent of the wires”. For penetration, we focus on the critical interface points that must be managed to deliver an end-to-end Digital Grid solution.

Based on the above parameters, our evaluation of communications infrastructure technologies to bridge the Fiber Gap is centered on four basic alternatives: BPL, Power Line Carrier, Wireless and Off-Grid Networks. The matrix presented in chart 2 assesses the ability of each of the four technologies along eight capabilities.

The first six capabilities are very specific communications network attributes derived from Digital Grid requirements, and form the basis of differentiation from a purely technical network design. The other two capabilities are based on deployment features, and include Network Optionality (e.g., attributes that maximize digital representation and control of the underlying physical grid) and Customer Optionality (e.g., attributes that can be exploited to accelerate customer adoption and experience).

Our assessment of Digital Grid creates some meaningful differentiation between the four available technologies. At the highest level, we conclude that either a BPL or an integrated Wireless system (combining two or more discrete wireless platforms) can deliver the functionality to enable the potential of Smart Grid. Between these two candidates, we believe that BPL has noteworthy competitive advantages in several areas.

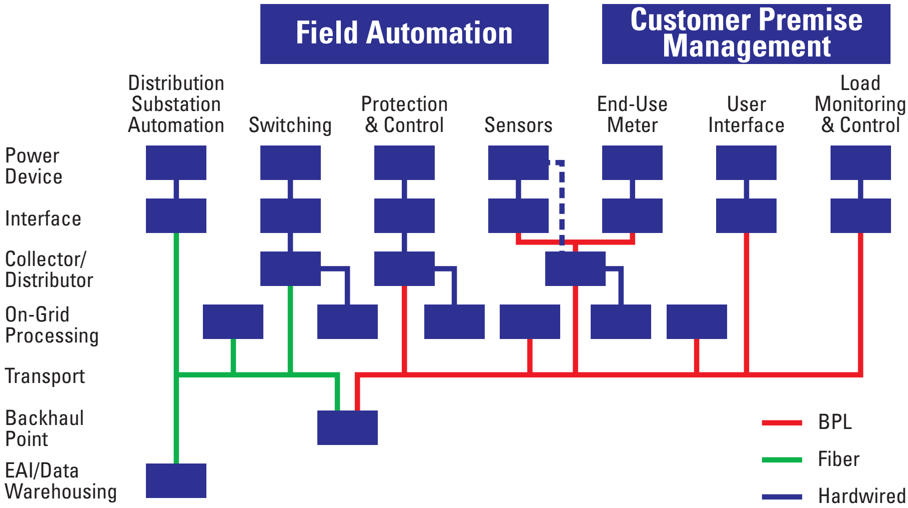

Chart 3

The other two technologies, Power Line Carrier and Off-Grid Options, are not highly viable for a full Digital Grid implementation. Both offer economically attainable capabilities when applied in one or a hand-full of point solutions, but in the design of the Digital Grid and development of the long-term business case for Smart Grid, we view these technologies as likely secondary choices with focused uses as network architects lay out longer-term infrastructure requirements.

On initial deployment, a Wireless network costs less than BPL in all but the densest and obstructed urban areas. Its speed and bandwidth are good, and improving over time as new wireless formats evolve. However, wireless does not touch the physical grid, and would require vast amounts of additional hardware to support true asset management and distribution automation capabilities. Also, multiple wireless formats are typically required along different segments of the network to optimize access and cost.

Looking at chart 2, BPL has the advantage over Wireless in three of the six technical capabilities and extends its advantage when deployment optionalities are factored into the equation. The information integration required to realize second- and third-tier benefits and the penetration of the communications backbone “beyond the meter”, are two critical aspects of a fully-visioned Smart Grid we will now highlight. In a conceptual communications architecture (see chart 3) these two capabilities combine to support the multitude of on-grid processing and inter-device relationships from substation to premise, and from both processors embedded within discrete field devices (e.g. a smart box in a customer’s home) as well as external processors managing aggregated field device data.

Of the available technologies, BPL offers the simplest and most efficient design solution to the “fiber gap”. BPL enables multi-tiered distributed processing within a single-platform technology, and can serve as the communications infrastructure from the point of fiber pick-up to end-use devices which are “beyond-the-meter”.

By contrast, the conceptual Wireless design (see chart 4) is far more complex, requiring at least two separate Wireless platforms for grid and home applications. The critical differentiators that we believe should be noted are the requirements to deploy, manage and maintain effective systems integration between utility-controlled wireless platforms and customer premise-based home area wireless network (HAN); physical device interfacing which requires both alignment of in-home standards and object integration between networks; and a choice between using the meter box or another separate home device to be the gateway between the two wireless platforms.

The Value of Optionality

If the broader vision of Smart Grid and the principles of Digital Grid are consid-

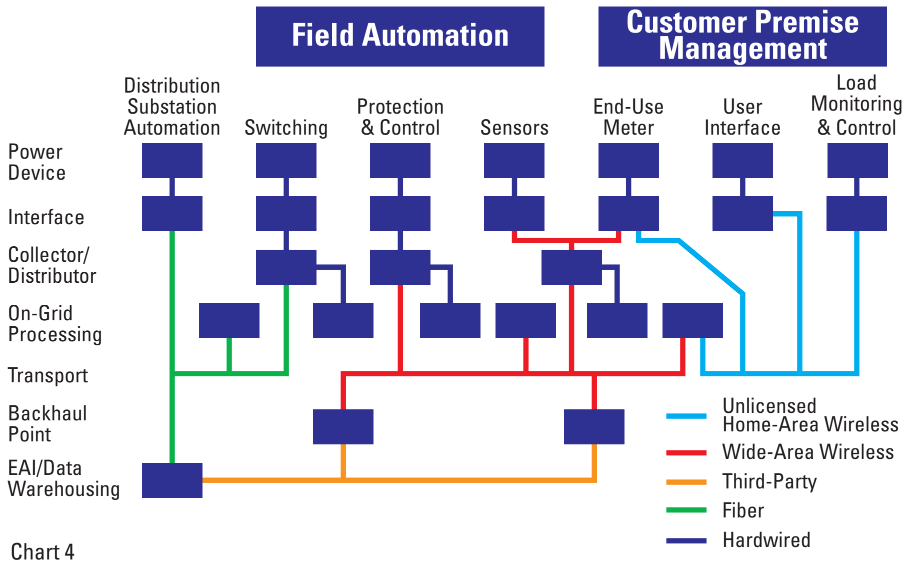

Chart 4

ered at the outset, we believe that in a number of instances the capabilities of BPL as a "through the wires" medium will provide utilities with a strong technical basis upon which to design a compelling and enabling communications infrastructure.

While both BPL and power line carrier technologies use "through the wire" medium, BPL's operating frequency and spread spectrum design requires that it jump every power transformer to maintain its signal. While this requirement results in BPL's largest "first cost" disadvantage, it is also a unique feature that enables important Network Optionality. BPL has the ability to embed within its deployment hardware the direct sensing capability of every secondary distribution transformer, by virtue of physical couplings on the high and low sides of each transformer with a distributed processor in between. This directly integrated physical monitoring provides a level of power flow and asset management that is unlikely to be economically realized with separate monitoring aligned to another communications infrastructure technology, like wireless. This direct physical overlay is the penultimate Digital Grid alignment, and is available on both overhead and underground circuits.

From the customer's point of view, BPL's distributed processing capabilities combined with the avoidance of a direct communications interface at the premise boundary create the broadest possible set of ways for utilities to offer customer information and communication channels while remotely managing the network's configuration. BPL deployments to the meter are comparable with other technologies, but in any deployment "beyond the meter", BPL is the least intrusive to the customer. As Smart Grid capabilities evolve and second- and third-tier integration requirements emerge, this Customer Service Optionality has the greatest potential to create significant delivery model differentiation.

Making the Case

Utilities pursuing Smart Grid will make critical strategic decisions at the outset of their grid digitization journeys, and will live with both functional and communications infrastructure commitments for an extended period of time. The need for a fair return-on-investment cannot be emphasized enough, and the regulatory dialog should focus on an integrated Smart Grid that accommodates new technologies for both grid and premise functionality. The "bargain" that must be struck between utilities and their commissions is like none other that has been explored on the distribution side of an electric utility. Utilities should be challenged to take a broad and far-sighted approach to both the role they should play and the basic investment decisions they must make. Commissions should expect utilities to pursue Smart Grid enablement beyond the benefits that just the distribution business can control, and should partner with their legislators to align the collective stakeholders around the full view of both tangible and social benefits.

Much of the Smart Grid attention has focused on metering, but we believe the bigger picture, and the equally enabling element to this last great technology transformation, is in the choice and design of the underlying digital communications backbone. Information architecture to deliver second- and third- tier Smart Grid capabilities will encompass way more than meter data, and the Digital Grid principles and functional capabilities that we have laid out should serve as benchmarks for the communications capabilities that will be required.

Put simply, the key strengths of BPL technology in building the communications backbone that will enable Smart Grid are the ability to ***touch***, ***reach*** and ***digitize*** the physical grid. Creating the most robust communications network requires that it ***touch*** the key nodes, like transformers, on the physical grid, and tackle the true complexities of the grid at the outset. For Smart Grid to be ubiquitously adopted requires ***reach*** beyond the meter in the least intrusive way. And end-to-end distributed processing from the head-end into premises and devices requires the network and information architecture to ***digitize*** both physical infrastructure behaviors and commodity and commercial flows. Bottom line - BPL provides requisite differentiation for utilities seeking to harness the true power of Smart Grid's end-game. ❑

About the Authors:

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