What is the real potential of the Smart Grid?

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I. Abstract

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Abstract Summary:

The electric utility industry continues to drive technology solutions toward a Smart Grid. This paper explains the differences between today's AMI systems and the capabilities of a Smart or Intelligent Grid (IG). The significant challenges of implementing Smart Grid technologies will be reviewed, including;

- The communications bandwidth requirements,
- The seeming lack of open compatible standards to allow a flexible architecture for various infrastructure requirements, and
- The push to implement AMI systems before Smart Grid technologies are mature.

The various potential benefits of a Smart Grid relating to Customer Satisfaction, Environmental Impact, Energy Efficiency and Operational Efficiency will then be described.

II. Define Smart/Intelligent Grid

Background

Intelligent Grids are nothing new. Manufacturing companies have been outfitting their factories with intelligent networks for more than two decades. Whether they are making microchips or potato chips, these companies can track all their manufacturing processes, their various inventories, and their distribution processes with great detail to drive efficiencies, quality, and service for their customers.

However, electric utilities are very different from chip manufacturers. Electric utilities' 'factory' has no finished goods inventory and no work in process inventory because supply must equal demand at all times. Unlike the chip factory, electric utilities don't send their product to customers using a trucking company. Their method of delivery uses a distribution system that physically connects the source to the customer. Additionally, unless operating on an actual island, electric utilities are interconnected with their neighbors and problems in one system can often affect everyone else. Outsiders often marvel that with these critical operational elements, the electric utilities' intelligent grids are significantly behind other industries.

Finally, today the technical and economic obstacles to utility intelligent grids are being removed and many electric utilities are now investigating the potential of an Intelligent Grid. Some are on the initial phases of implementing a pilot project and others are moving forward with a significant investment. Nearly all of these projects are usually driven by new AMI systems. In a recent report Will McNamara, Principal Consultant, KEMA, Inc. suggests that "although in many ways AMI technologies are maturing, they can hardly be characterized as being fully mature at this point. While concerns about inadequate technologies and customer interest linger, a significant number of U.S. electric utilities – including many of the industry's major players – are taking leaps of faith towards developing AMI/Smart Grid strategies." [1]

Definition and Benefits of IG

So what exactly is an Intelligent Grid? The following definition offered by Ethan Cohen with UtiliPoint, captures the meaning. 'An Intelligent Grid refers to an electricity transmission and distribution system that incorporates elements of traditional and cutting-edge power engineering, sophisticated sensing and monitoring technology, information technology, and communications to provide better grid performance and to support other utility business processes especially service delivery and customer service. In general, an "Intelligent Grid" should not be defined by what technologies it incorporates, but rather by what it can and does for utilities and their customers.'[2] This definition illustrates one of the core challenges toward understanding the potential of the IG. The IG is more of an application of various technologies and architectures than a traditional capital project. Essentially, each utility will implement the specific technology based on company goals and objectives. The true value of the IG is based on the capabilities of that grid and the nature of the monitored electric infrastructure. Consequently, the value derived from the IG is vastly different from one utility to another.

To better understand the potential of an IG, it is helpful to first understand most utility's primary IG objectives. The goals break down into four areas.

- **Customer Satisfaction**

  This includes improved meter accuracy, outage reduction, improved power quality and voltage stability and outage detection. It also includes improved restoration feedback and the reduced loss of customer's opportunity costs from outages.

- **Environmental Impact**

  This impact captures the Greenhouse Gas (GHG) savings from generation reduction from Energy and Operational Efficiency improvements. Differed generation or off grid purchases is included. It also includes reduced CO2 from reduced truck rolls for service calls and reduced patrolling for line faults.

- **Energy Efficiency**

  This includes reduction of system losses, peak management, distribution voltage/VAR management, and improved asset utilization.

- **Operational Efficiency**

  Operational efficiency is obtained through the reduced costs of meter reading. Includes improved electrical system design, standardization, optimizing operation, and remote connect/disconnect benefits. It also includes the integration of DG and Net Metering, reduction in trouble call volume and improved efficiency of aging asset utilization.

IG Architecture

Figure 1 contains an example block diagram of the Intelligent Grid. This drawing highlights the Intelligent Grid's major communications systems:

- Operational and Non-Operational Networks feeding data between applications and users.

- Utility Remote Network – usually connected to the non-operational network feeding data to field personnel.

- A number of high speed backhaul networks that communicate data from various gateways or data concentrators.

- A substation network usually consisting of at least two real or virtual networks – Operational and Maintenance (also called non-operational). However, since few utilities are implementing the process bus and few suppliers are including it in their products, it fits better as a potential future portion of the IG.

- The Backhaul networks also connect to various Distribution networks that communicate with intelligent devices throughout the distribution system including the meters.

- The Home network – Many IG solutions include a tie to the customer's home LAN, including smart thermostats, personal computers, DSM devices, distributed generation. This connection is sometimes made through the communications portion of the meter.

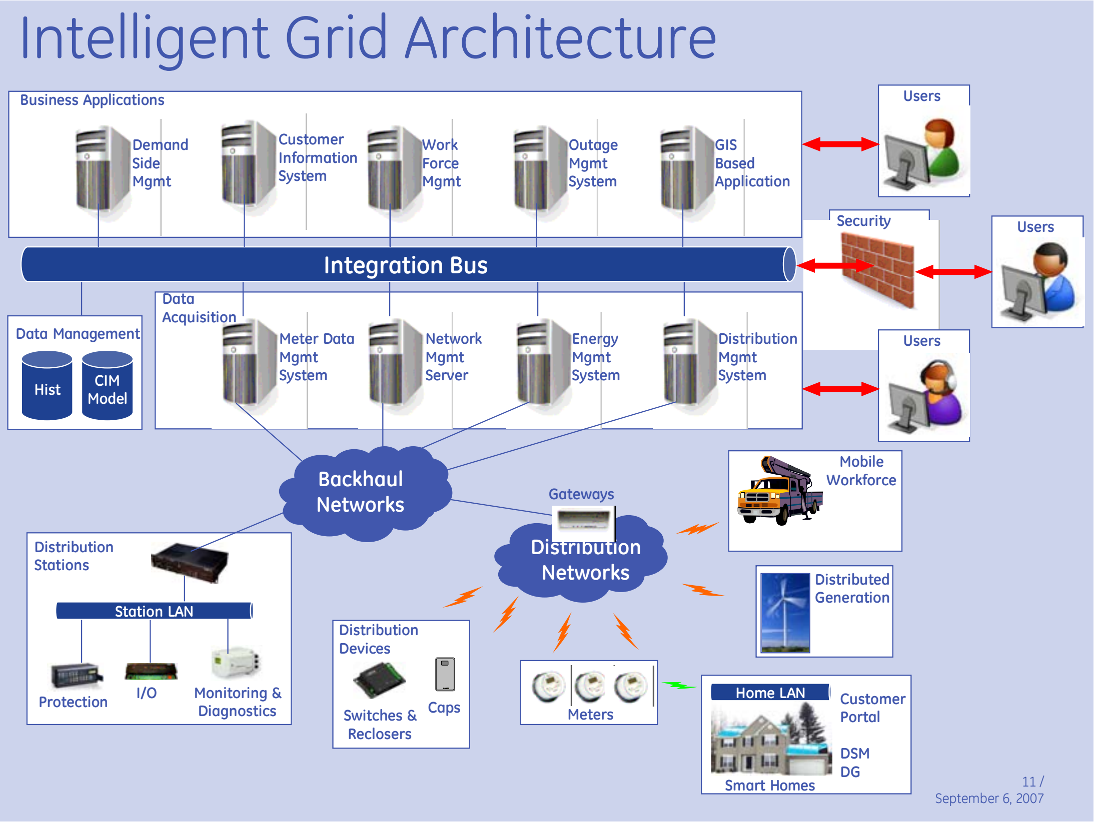

Figure 1: Example Intelligent Grid Architecture

Obviously, this architecture shown in Figure 1 is one example and each utility will implement IG differently. However, any discussion of IG's real potential must go beyond AMI. The Intelligent Grid is more than just an AMI system communicating to advanced electronic meters. Furthermore, this architecture highlights the fact that for many years, utilities have been operating an IG from their substations through a backhaul, providing valuable information to the operational and non-operational personnel.

Many of today's AMR systems support elements of the IG. However, they will not reach IG's full potential due to several important limitations. Simply supporting the ANSI C.12.22 standard provides improves the flexibility of metering to communicate with various communications architectures, however, it is only a one step toward a true IG. Supporting the ANSI standard does help the metering system become more agnostic regarding the communications media supporting data packets over cellular communications, licensed or unlicensed wireless, power line communications, or satellite in rare cases. To reach the full potential of the IG, the communications grid must support non-metering protocols and non-metering applications. Support of other Intelligent Electrical Devices (IEDs) in the distribution system such as capacitor or switch controllers, fault detectors or distribution capacitor banks allows significant incremental improvements in Customer Satisfaction from shorter outages. Energy Efficiency and Operational Efficiency and provides the greatest reduction in Environmental Impacts.

Previously, the costs and technical challenges of deploying a communications infrastructure to the non-metering distribution devices have restricted the ability to capture the efficiency gains. A truly open AMR system improves the economics by leveraging the communication infrastructure for uses other than AMR. For example, the ability to communicate with distribution switches over the IG allows the ability to automatically isolate faults and restore un-faulted sections of load. Communicating with distribution capacitors over the IG allows control of the voltage while improving the station and region VAR management.

III. Leverage Existing AMI Systems

There are three factors which tend to limit the ability of many of today's AMI systems to meet the full potential of the Intelligent Grid. The AMI system's communications capabilities, architecture flexibility and existing AMI system focus.

1 – Communications capabilities

The focus of many utilities when implementing an IG architecture has been on implementing an AMI system. Many of today's AMI systems meet some of the functional requirements to fully capture the benefits of an Intelligent Grid. The primary communications capabilities consist of bandwidth, two way communications and support for other non-metering IEDs.

The Bandwidth requirements of an IG focus on retrieving more information from the system than periodic energy readings from the meter. Especially when today's systems aggregate several thousand meters on the same communications channel and energy readings are retrieved daily or hourly. This includes the periodic retrieval of voltage and PQ values. Additional bandwidth requirements are placed on the system for integration of Supervisory Control and Data Acquisition (SCADA) of switches, fault detectors, capacitor controllers. The total minimum bandwidth for a typical fully functional system is about 100 kbps.

The ability to handle two way communications is also critical for features such as polling for specific values, SCADA, or remote disconnect. Also, if communications to critical SCADA devices, outage detection or fault detectors is required, these power sources will require a backup. Power supplies for critical communications infrastructure is often backed up however, outage detection from meters requires some backup power. To avoid having a battery, some meters support a short term energy storage permitting a "last gasp" communications while others can be inferred to be off-line when polling stops.

Communications support for other IEDs and SCADA devices will provide a significant improvement to the benefits of an IG. This requires the ability to support SCADA protocols. Fortunately, there are many types of open SCADA protocols supported today. In North America, DNP is the most common protocol.

2 – Architecture flexibility

The architecture of IG must be flexible to adapt to the varying physical constraints of the distribution system. Optimizing the functionality and managing the associated system costs are much more difficult with a 'one technology fits all' approach. System designs need to balance the different requirements between urban and rural densities, geography, sources of RF interference, and other physical challenges of the last 100 yards. A flexible solution that includes supporting communications over licensed and unlicensed RF, leased wireless and cellular communications, PLC and BPL communications and occasionally satellite.

3 – Emphasis on AMR

However, the biggest factor limiting the ability of AMR systems today is not technical capability. The largest limitation is based on the nature of how Automated Meter Reading systems have been historically deployed and added to the rate base. The traditional AMR system is based on proven technology with utilities relying on purchasing new system where hundreds of thousands of meter systems have been previously been deployed. These systems tend to be more cost effective based on the single task of meter reading. These systems focused on reducing the costs through automatically reading meters and the benefits were easy to communicate to utility management and regulators. However, the systems tend to be proprietary and not adaptable to other uses and consequently not capable of capturing the benefits of an IG.

This challenge with justifying IG is emphasized by Michael Burr in ‘Public Utilities Fortnightly’. “The smart grid, however, is somewhat trickier to define, and offers different benefits for utilities depending on their operational systems, market structures, and load profiles. It never has been implemented on a large scale by any utility in North America, so it can hardly be called a mature technology--even though most of the hardware behind it is relatively well proven. Building the intelligent grid will require less technical innovation than it does strategic innovation . . .”[3]

The nature of IG is evolutionary. New advances are always being made. This makes an IG project much more risky and much more difficult to predict the life expectancy of a system. The interdisciplinary nature of the IG means it touches a significant number of utility operations and maintenance systems and processes, making it difficult to manage and the complex benefits much more difficult to measure and justify to management and regulators.

IV. The IG Potential

The average costs of an IG system per meter for a fully deployed system can be very challenging to fully quantify and can run in the hundreds of dollars per meter. The benefits are also difficult to fully calculate as they tend to involve long-term tangible and intangible benefits from many portions of the utility. These include the increasingly important but difficult to measure societal benefits of reducing customer outage minutes or reducing greenhouse gas (GHG) emissions.

The total value of an IG for a particular utility will depend on many factors, including their electrical infrastructure, the dynamics of their load, the needs of their customers and the utilities regulatory environment. The incremental benefits of an IG will also vary depending on benefits of the utility's existing systems. The impacts of each of these benefits on Customer Satisfaction, Energy Efficiency, Operational Efficiency, and Environmental Impacts can be significant. These benefits have been derived from the following items.

Reduced Onsite Premise Presence / Field Work

This IG benefit deals with the traditional AMI capabilities to reduce onsite field personnel visits primarily resulting from remote meter reading, remote programming of meters. It also includes more advanced capabilities of remote connect/disconnect, remote verification of power restoration and reduction of outage minutes. The reduction of outage minutes for a system receiving outage notification from meters is around 10%. However, the reduction is 35% once the ability to communicate with distribution line fault detectors and field switches is added to the IG.

Enable Customer Self-Service / Reduce Call Center Inquiries:

This IG benefit focuses on reducing call center inquiries by improving quality of service and by enabling customer self service information access through an IG web portal and IVR. This includes information on their energy use profile to guide energy usage decisions; the improvement of meter reading accuracy, notification of outage occurrence and restoration thru integration with an IVR calling program. The benefits from automatic identification and correction of low voltage conditions should reduce the number of customer complaints and the ability to find trends of excessive energy use at a location should lead to early customer notification of problems which should help avoiding billing disputes.

Improved Revenue Collection

This benefit includes the value of eliminating estimated bills and the revenue element of improving meter reading accuracy. Once supported by their rate structure, the addition of frequent meter reads and remote disconnect brings the capability to enable prepay metering. Prepay billing improves the revenue collection from customers with a history of very late or no-pays.

Shorter Outage Durations

As stated earlier, the full potential of the IG to reduce outage durations includes communications with more than the meters. Communications with line mounted fault detectors and with switch controllers can reduce the outage duration 35% or more. Once faults are detected at the meter or at a field installed fault detector and localized by automation algorithms, the fault can be automatically isolated through communication to remote controllable switches along the feeder. Then alternative sources can restore un-faulted sections of the feeder. The integration of fault information with Distribution Management Systems (DMS) and Outage Management Systems (OMS) systems and improved Geographic Information Systems (GIS) further improves the dispatcher's ability to deploy field service crews. Once the fault is cleared and power is restored, communication with the meters helps identify the possibility of nested outages. This capability also proactively reduces faults by providing critical data to improve vegetation management, line upgrades and line maintenance.

Reduced Energy Losses

This benefit captures the identification and reduction of non-theft line losses thru aggregation of load and voltage data at points throughout the network. Then through IG communication with distribution line capacitor banks, automation algorithms further reduce line losses through improved substation and region power factor management. This has the side benefit of reducing wear-based maintenance required on station transformer based load tap changers.

The IG system can achieve additional energy loss related value with the identification and reduction of energy theft and meter tamper detection notification.

Reduced Greenhouse Gas Emissions

Reduction of GHG emissions has become very important in today's society. Some of the benefits of the IG do have impacts on reducing GHG. These are related to delayed investments in new fossil generation primarily resulting from DSM and energy loss reductions. There is also a reduction in GHG emissions due to fewer truck rolls from meter reads, fault locating and outage restoration.

Optimized Transformer Operation

The IG can help improve the operation of distribution and substation transformers by better understanding the loads and load profiles which can be obtained through aggregating associated meter readings. The utility can then take the appropriate maintenance actions, or to adjust the network operations for optimum transformer operation; network voltages. The health and maintenance schedule of the LTC, arguably the most troublesome part of a station transformer can be drastically improved through a more optimal operation of the distribution line capacitors. Additionally oil and temperature monitoring on the station transformer communicating through the IG will help improve the utility's operations and maintenance practices and reduce catastrophic failures that result in lengthy outages and significant costs of replacement/repair of failed transformers and associated station equipment.

Standards & Construction

When implementing an IG is an excellent opportunity to capture additional benefits from adopting more efficient feeder design standards and construction techniques. Much of this improvement comes from a better understanding of feeder data (loads, voltage, power flows) provided through the IG. Integrating this data with planning and design tools provides a complete picture of loads over time along entire feeder allowing engineers to design with smaller safety factors and properly size the equipment to match the application while considering projected load growth. Further benefits come from the standardized designs for new meter replacement inherent with installing a new IG across the system.

Improved Network Operations

Further IG benefits come with more accurate and detailed voltage, current and load readings across the feeder, allowing distribution network operators to improve capabilities in tuning the system for voltage, phase balance, and power factor control. Integrating Distributed Generation and net metering at customer sites also result in improved system management.

Reduce Integration & IT maintenance cost

There are additional benefits in data management associated with the integration of various applications in the back office. Data management reduces data duplication and improves data accuracy, eventually reducing costs for mapping data between applications and devices. Support of open standards, non-proprietary systems and support of common information models (CIM) allows for efficient data sharing as needed by multiple applications.

Active Demand Side Management

Use of active demand management devices built into the IG allows the Utility to reduce peak demand directly by allowing certain loads to be turned off. Better load management significantly reduces peak demand, saves costs of capacity construction, improves system stability and reduces forced outages.

Condition based Asset Maintenance / Inspections

With more automated voltage, current, load reading, equipment cycle information, etc., the maintenance needs can be based on the condition of the equipment in question, and not conducted solely based on a prescribed, periodic frequency.

Momentary Trips - directed Vegetation Mgmt

The need for tree / vegetation trimming can be further enhanced using information from the meters and field based fault detectors to identify and locate differential momentary trips, combined with an overlaying of wind direction from field based weather detectors, and which way the laterals/feeders are running. This information can also be used to improve the fault location when traditional methods are inconclusive due to branching circuits.

Delayed Generation & Transmission Capital Investments

Use of the valuable information gathered and the associated improvements to load management and operational efficiency, capital construction can be deferred including delaying construction of new generation to meet peak load requirements or upgraded transmission and distribution facilities to address congestion problems. The system will also help prioritize capital investments.

V. Conclusion

This paper has presented a summary of typical benefits of an Intelligent Grid. To completely understand the full benefits, each utility exploring the benefits must conduct a complete assessment of the costs and benefits of IG functionality beyond the more obvious benefits of a smart AMI system. Only then will the full potential benefits of the IG be realized for to improve Customer Satisfaction, to reduce Environmental Impact, and to optimize Energy and Operational Efficiency.

VI. End Notes

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[1] "Many Utilities Starting to Develop AMI and Utility-of-the-Future Strategies", 05/29/2007, Will McNamara, Principal Consultant, KEMA, Inc. http://www.kema.com/consulting_services/cross_sector/management_support_services/strategic_metering_services/automation_insight/August_2007/Cost_Recovery.asp

[2] "Utility Technology Innovation: Getting to the "Smarter Grid" UtiliPoint Daily IssueAlert, 7/18/2006 By Ethan L. Cohen, Senior Director, Utility and Energy Technology http://www.utilipoint.com/issuealert/article.asp?id=2704

[3] "Smart grid, smart utility: the intelligent-grid vision is becoming clearer as utilities take incremental steps toward a brighter...", Public Utilities Fortnightly, - 2/01/2007 Michael T Burr, Editor-at-Large http://www.allbusiness.com/utilities/utilities/4056440-1.html