SMART GRID INTEROPERABILITY PANEL

Broadcast-based H2G Communication Solutions

A white paper developed by the Smart Grid Interoperability Panel
November 4, 2013

Document Source: Home-to-Grid (H2G) Domain Expert Working Group (DEWG)
Author/Editor: Jackson Wang, e-Radio, Kevin Brown, EnerNex, Conrad Eustis, Portland General Electric, Ken Wacks, H2G DEWG chair, GridWise Architecture Council
Production Date: November 3, 2013

Disclaimers

- The information contained in this document is the proprietary and exclusive property of SGIP 2.0, Inc. (SGIP) except as otherwise indicated. No part of this document, in whole or in part, may be reproduced, stored, transmitted, or used for design purposes without the prior written permission of SGIP.
- The information contained in this document is subject to change without notice.
- The information in this document is provided for informational purposes only. SGIP specifically disclaims all warranties, express or limited, including, but not limited, to the implied warranties of merchantability and fitness for a particular purpose, except as provided for in a separate software license agreement.
- This document adheres to the SGIP Intellectual Property Rights (IPR) Policy.

Acknowledgements

Jackson Wang, e-Radio
Kevin Brown, EnerNex
Conrad Eustis, Portland General Electric
Ken Wacks, H2G DEWG chair, GridWise Architecture Council

Contents

Contents

1 Executive Summary

Power utilities may significantly reduce operating costs and increase grid reliability if appropriate control/pricing signals are sent to assist the balancing of power supply and demand. By sending location-specific prices to devices, it is possible to leverage and optimize the inherent energy storage and/or consumption capability in residential load consuming appliances in real-time. Since the time of Thomas Edison in the early days of electricity, radio broadcast communication tools have been used by utilities to limit loads at times of system peak demand. More recently in 2008 the Sacramento Municipal Utility District (SMUD) demonstrated broadcast communications to improve building energy efficiency [1]. SMUD used OpenADR and the Utility Message Channel from e- Radio to reach 78 programmable communicating thermostats (PCTs) at small commercial sites with FM broadcasting, achieving bill savings of approximately 30%. In a similar study providing time-of-use (TOU) and critical-peak-pricing (CPP) data to residential programmable communicating thermostats (PCTs), customers realized savings of up to 19% on their electricity bills and the utility received DR load reductions of up to 58% (kW) from individual premises during peak periods [2].

This paper explores a new paradigm for the consumer-centric use of broadcast tools. This proposal leverages existing facilities to broadcast localized real-time pricing/status of the smart grid to all devices in the receiving area. Feedback or confirmation of loadshed characteristics can be obtained by data mining at the feeder or sub-station level. These data are inherently aggregated so end-user privacy is maintained. The payoff of this approach is potentially acquiring a greater volume of time loads more quickly and cost effectively than any current alternative. Furthermore, broadcast solutions utilizes the existing FM radio infrastructure while preserving customer privacy without introducing new local radio frequency emissions. FM radio broadcasters are authorized to carry digital data in addition to audio using the Radio Data System (RDS).

Self-installing broadcasting solutions can eliminate or greatly reduce the cost, complexity, and installation time compared with the requirements for a two-way communications system to end-devices. One practical example is the inherent need to set the SSID and password in a Wi-Fi device. The use of secure Wi-Fi requires a display screen along with keyboard or buttons either on the device or via yet another port such as USB to facilitate programming configuration data into a consumer device. The broadcast method can also potentially solve some of the issues encountered by localized two-way transmitters, such as Zigbee from smart meters, that do not work well in multiple occupancy homes or small businesses due to lack of signal coverage. The broadcast solution can be complementary to optional Home Energy Management or networking systems by providing an independent live input to the local network. Since receiver-only devices tend to consume less power than transmitters, the broadcast architecture could also minimize phantom or standby power consumption. The one-way broadcast method can also be extremely secure, not unlike the protected and time stamped one-way broadcast of ELF (extremely low frequency) nuclear launch commands to submarines. In the case of smart grid broadcast, authentication codes can be built into the silicon to authenticate messages, which may include public/private key methods [3]. In this case, any compromise of the public key in the receiver will not compromise the integrity of the system.

The recent growth of wind and solar resources in the supply-side mix has added significant complexity to load/resource balancing requirements. But new control methods with loads such as electric vehicles or existing loads with inherent energy storage such as water heaters on the demand-side creates opportunities for simple low cost control optimization solutions. In the case of large industrial, commercial or institutional customers, sophisticated communication solutions can be put in place to achieve load balance. These solutions typically are expensive and complex but can be justified by the load sizes and benefits achieved. In the case of residential and small commercial customer sectors, the sheer number of end-use devices in the field demands a more economical and standards-based approach. Such a solution must be easily and readily scalable, easy to adopt and able to harness a limitless number of devices. The purpose of this paper is to investigate the merits of radio broadcast methods to meet these requirements.

2 Whither Radio Broadcast

The modern smart grid is a complex system of electric supply and demand with increasing market penetration of renewable and bi-direction micro grids. It is therefore logical to assume that a myriad of communication solutions need to be developed to accommodate for this complexity. The interactive smart grid systems already have a likely biological analog. Our human bodies are perhaps one of the most complex systems on earth with a variety of interactive and real time sub-systems optimized to operate autonomously over a reasonably long period of time. Just as there are a number of intrabody communication systems such as the endocrine-based hormonal system and synaptic based CNS (central nervous system), it is logical to assume that there is no singular communications for all of the requirements of the smart grid.

In 2006 Heffner [4] proposed a SCADA system for measurement and verification of actual load reduction as a result of demand response programs. We are adapting this concept to reach grid customers with broadcast communications to end-user devices in combination with feeder/sub-station SCADA systems. This hybrid system can potentially scale economically and quickly by trading resolution for simplicity. One of the key characteristics of broadcasting is the ability to expand without limit the number of simultaneous listener devices. This by itself is a good reason to consider broadcasting as a primary tool for smart grid home-to-grid (H2G) communication solutions. Other important traits of broadcasting include end-user privacy preservation and the ability of the broadcast system to complement HEM (Home Energy Management) and AMI (Advanced Metering Infrastructure) systems.

We believe that the following list sets out important factors that should be considered in the development of objective performance indices for smart grid communication solutions:

1. Market coverage
2. Nationwide interoperability (physical, application layers etc.)
3. International compatibility for OEMs
4. Redundancy and reliability
5. Security
    a. Signal authentication
    b. Physical (building/infrastructure)
    c. Cyber
6. End-user Privacy, eg, Consumer products/settings via simple color codes
7. Time stability of solution
8. Ease of System integration
9. Time to pilot & full scale deployment
10. Availability of receiver Hardware
11. Capital and operating cost of infrastructure
12. Capital and operating cost to consumer devices
13. Consumer centric characteristics
    a. Standardization is needed in three aspects:
        i. Standardized price and/or control signals,
        ii. A low-cost, low-latency, ubiquitous communication path to the loads, and
        iii. End devices, when standards are in place, at nearly the same price as today that can be responsive to the standard application signal.
    b. Some of the required consumer centric characteristics particularly well suited to the broadcast based solution as highlighted by the PNNL paper [5] are as follows:
        i. Requires very little, or no consumer interaction whatsoever. (line 50)
        ii. Fastest to implement (line 249)
        iii. Minimizes costs
        iv. Single standard nationwide coverage (line 122)
        v. Informs consumers while preserving privacy (line 379,389)
        vi. Enables consumer override capability at any time (line 379)

3 Price Information Enabling Automated Demand Response

Most devices that use electricity either have thermal inertia (e.g., heating, cooling, water heating, and refrigeration) or potential flexibility as to when they take power from the grid (e.g., industrial pumping loads and batch processes, pool pumps, dishwashers, clothes dryers, and charging of electric vehicles and battery powered devices). While many of these end-use devices have built-in intelligent controls, they lack information about when it would be most economical to use power from the grid. An inexpensive, standards-based approach for communicating present and near-term energy prices could rapidly lead to the deployment of millions of devices that would automatically and continually adjust the timing of their electricity use in response to grid conditions without materially impacting the consumer's experience. (In some cases, the customer experience would actually be enhanced such as blackout restoration and emergency advisory messages in battery-backed circuits and displays in host devices.) In the aggregate, such devices could provide a large flexible resource. This response could help compensate for the output variation in large, renewable resources, improve utility asset utilization and lower costs, enhance reliability, facilitate demand response, and remove a key barrier to efficient retail pricing. [6]

4 FERC Authority

EPACT (Energy Policy Act of 2005) §1281, amending §220 of the Federal Power Act, directs FERC to "facilitate price transparency in markets for the sale and transmission of electric energy in interstate commerce" and authorizes the Commission to create rules that, "shall provide for the dissemination, on a timely basis, of information about the availability and prices of wholesale electric energy and transmission service to … the public." FERC is given express authority to, "establish an electronic information system if it determines that existing price publications are not adequately providing price discovery or market transparency." [7] FERC also has jurisdiction over ISO/RTO demand response programs. Thus, data about when it would be economical to use electricity should be available to any device, anywhere, at all times, as inexpensively as possible, and with little or no change in consumer behavior required.

5 Projected Impact of the Connected Water Heater

Water heaters have approximately a 15-year life cycle. Thus each year the US market waits to develop this resource, it will lose (for 15 years) the opportunity to develop a 1,400 MW1[1] resource that could have been economically built to offer varying renewable loads on a real-time basis. At half of the net present value cost to build and operate an equivalent, flexible peaking resource of approximately $5 billion dollars2[2], the country loses a savings opportunity of about $2.5 billion per year. With a realistic market adoption of 50%, the lost saving is still $1.25 billion

[1] From U.S. Census data installed units represent about 42 million electric water heaters; About 2.8 million new/replacement water heaters are sold each year. If all were sold with a standards-based communication interface, such as CEA-2045, then these water heaters represent an economic resource to mitigate 1,400 MW of peak load assuming an average, avoidable, coincident, on-peak demand of about 0.5 kW per water heater.

[2] The analysis assumes the 30-year present value of revenue requirements (~$215 per year per kW to build, fuel operate and maintain a flexible resource designed to operate over a wide power range to compensate for swings in output from a renewable resource such as wind; total operating time about 1800 hours per year.

per year. The authors know of no other resource of this magnitude that can be developed this cheaply, and used every day of the year. Using proven methods, there are no fundamental technology barriers to developing this resource. [8]

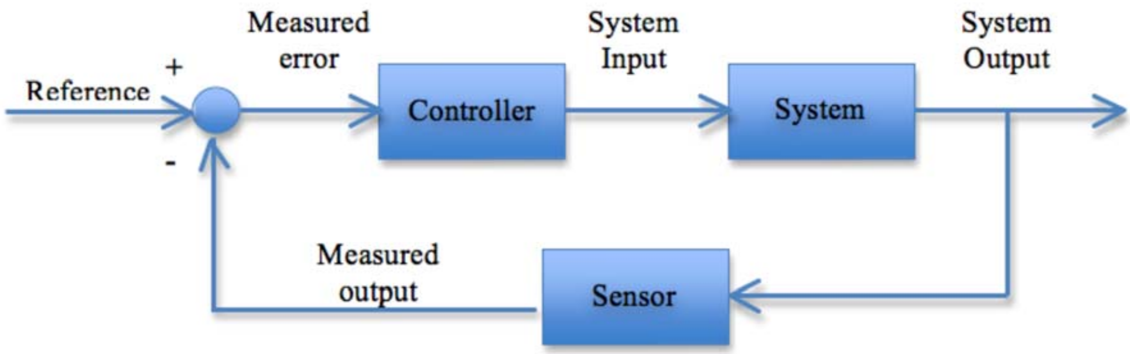
6 Transactive Energy

Transactive Energy is an automated strategy for balancing the supply and demand for electricity. Traditional "load following" adjusts supplies, while Transactive Energy introduces market and technology methods that adjust both supplies and loads to achieve balance. Thus, both utilities and customers will participate in Transactive Energy. Transactive Energy (TE) combines market forces and control techniques to achieve grid balance automatically. In a TE environment, power-producing devices may offer excess power to the grid via a market bid-and-ask mechanism. The device or an aggregate of devices would propose power at a specified level and time, which could be a few minutes or hours later. Loads on the grid bid for this power, a price is agreed, and the power is delivered when promised to settle the trade. The price and power data are exchanged among the devices via a network using machine-to-machine (M2M) communications. [9] The broadcast mechanism can be a very useful tool in facilitating the Transactive Energy concept especially if grid specific information can be attached for optimizing feeder and sub-station capacity issues. The feedback channel could be user/device specific as well as aggregated in feeder/sub-station potentially by a third party, which can then bid/ask in aggregate.

The broadcast mechanism can be a very useful tool in facilitating the Transactive Energy concept especially if grid specific information can be attached for optimizing feeder and sub-station capacity issues. The feedback channel could be user/device specific as well as aggregated in feeder/sub-station potentially by a third party, which can then bid/ask in aggregate.

7 Classic Control Theory and System Stability

One can view the electrical grid transition from an open loop to an optimized closed loop as making the grid "smart". The provision of real time information to load devices fits well to the concept of classical feedback control theory:



In this case, the "reference" signal indicates the desired consumption required by a feeder, substation or aggregate utility. The differential "measured error" signal represents the amount of increase or decrease in the load desired for that circuit. The "controller" calculates appropriate "forward/predictive pricing" and broadcasts it to the target areas formulating the input to the "system". Completing the closed loop, the "sensor" measures the actual consumption by the feeder, substation or utility wide aggregate to provide the feedback that is compared to the reference input. System stability could be achieved with an accurately modeled closed-loop transfer function by calibrating the individual components of the system according to control theory. An example of parameters available to calibrate the controller output is the pricing and the number of target loads addressed.

Recent investigations into mining feeder and substation data suggest that this approach is viable. In some specific field feeder samples, a resolution of 1 kVA can be observed in 10-second intervals. Since the consumption of the typical water heater when on is approximately 2.5 to 5 kVA (for resistive devices, kVA is equal to kW), the effects of a significant number of connected water heaters can be observed. Therefore, in feeder lines that have a reasonable amount of consumer device loads connected via FM broadcasting, real time consumption characteristics can be measured via the existing or upgraded infrastructure to mechanize the feedback to the utility without compromising customer privacy. The application of a rigorous and calibrated mathematical model of the grid could yield new insight, as the optimized operational strategy for consumer friendly smart grid control may not be obvious. This work would go beyond the scope of this paper but could be a useful academic project that benefits the industry.

8 Technical Requirements of the Broadcast Solution

	FM (National Radio Systems Committee) [10]	**NOAA (National Weather Service) [11],[12]**	**PAGING**
1. Signal Coverage			
1.1. National	Yes (99% of pop.)	Yes (95% of pop.)	Yes. Verizon claims

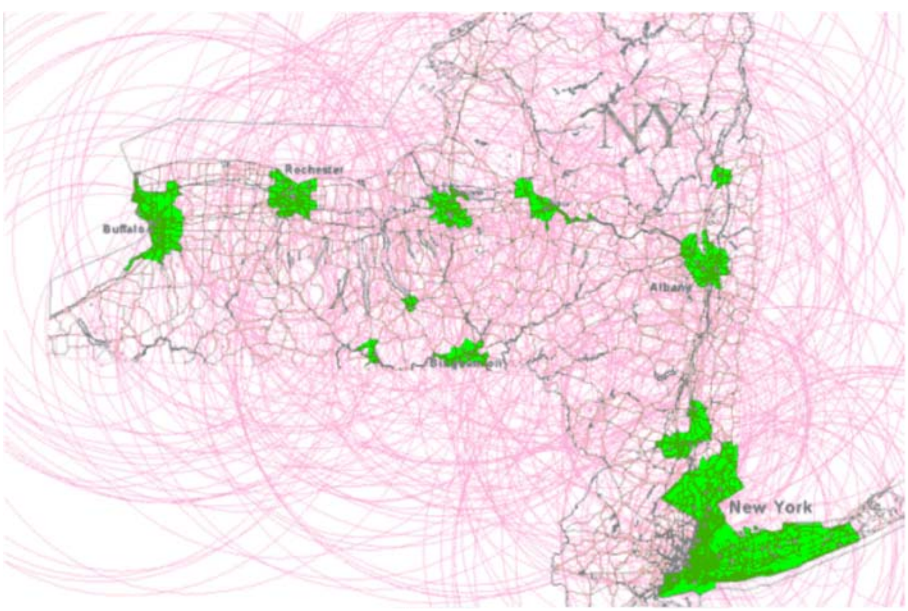
			coverage in the top 150 major metro areas and beyond in all 50 states [13]
1.2. Global	Yes, same standards	No, except small overlap with Canada near the border.	Yes, but different variations and standards are used
2. Performance			
2.1. Data Rate	RDS: ~1200 bps (~400 bps for applications after overhead) HD: A variable share of 300 kbps	520.83 bps	POCSAG 512- 1200 bps. [14] FLEX: Up to 6400 bps. [14]
2.2. Signal Latency	As low as 2 seconds, Nationwide	Unknown	Unknown
2.3. In-building Reception (RSSI, error rate)	Typical home and basement penetration within protected contour	Typical home Penetration	Unknown
2.4. Error Correction	Yes (10 correction bits for every 16 data bits; can correct multiple bit errors)	No (only synchronization only by header preamble)	Yes. Varies according to protocol used.
3. Security			
3.1Authentication/ Encryption Capable	Yes	Not currently	Unknown
3.1. Infrastructure			
3.1.1.Physical			
3.1.2.Cyber (defenses against hacking)			
3.1.3.Multiple Frequencies or Transmitters	Multiple transmitters and frequencies in most markets	Singular tower & frequency coverage	Singular tower coverage in most cases
4. Redundancy of Key Elements			
5. Role of Network Path (for hybrid with two-way)			
6. Time Stability of Technology	Decades of stability demonstrated, technology does not have known sunset period HD Radio already in place and can co-exists with FM-RDS	Decades of stability demonstrated, technology does not have known sunset period	Decades of stability demonstrated, however, possible sunset period for frequencies
7. Location Filtering or Targeting	Group, Geographic and Serial Number addresses are possible	County/Sub-county by predetermined code list	Individual Device targeting

9 Broadcast Technologies in fulfillment of the requirements, expansion of the comparative table above

Overview of FM broadcasting

FM broadcasting offers considerable value for demand response applications given its ubiquitous deployment, good building penetration, robust reliability, and low delivery and consumer-equipment cost. For the broadcast systems described in this paper, the infrastructure already exists as "low hanging fruit" – reducing time to implementation as well as overall capital expenditures. It also eliminates otherwise needed environmental assessments, reviews, and regulatory impact studies. FM broadcasters are authorized to carry RDS (Radio Data System) digital signals in addition to audio channels. [8] Consumers use RDS for station, song, and artist displays on car radios. There is excess capacity in the RDS channel that station owners can rent.

RDS distribution offers the benefit that the market coverage of an FM station is typically well matched to the service area of electric utilities in that market. This enables a form of addressability inherent to the terrestrial propagation footprint of FM stations. And, since broadcast infrastructures already have a primary business application, the operating and maintenance costs of operating this network would be shared, considerably reducing the overall expense.



FM Transmitter Coverage Circles for NY State FCC licensed stations

FM broadcasting enables smart appliances by providing them with real time price information, vastly improving the efficiency of the way that an appliance buys the power it needs to serve the consumer. In addition, a simple message display terminal can be addressed by utilities, to alert and advise consumers regarding energy usage during critical periods and to provide an alternative messaging channel for other important information.

Radio broadcast-based demand response does not limit the use of Home Energy Management (HEM) systems. HEMs can have an FM receiver in any of the connected devices and the real time pricing and other information received by broadcast signals can then be shared in all the other devices of the HEM. This capability was shown in various ANSI/CEA-2045, *Modular Communications Interface for Energy Management,* interoperability events hosted by EPRI. [ANSI/CEA-2045 is an American National Standard approved in 2013. It was proposed by the H2G DEWG in 2011 and offered to the Consumer Electronics Association (CEA), a Standards Developing Organization.]
The following smart applications are supported because of the fast response time and full market coverage of RDS:

- Improved Demand Response (hourly, minutes, seconds);
- Increased frequency regulation and spinning reserve applications;
- Enhanced integration of renewable generation;
- Hourly and more advanced dynamic pricing schemes.

Broadcast with group addressing capability enables location specific response to: reflect time & location specific marginal costs; alleviate specific distribution constraints; leverage use of location based services (LBS) technologies provide 5-minute location marginal price (LMP). Transactive energy schemes for renewal generation integration.
The innovative use of RDS for utility load management in smart grids represents a Winwin situation, wherein utilities can rebalance electrical loads with low cost optimization strategies and broadcasters can collect new non-traditional revenues by providing valuable energy management services to their communities. FM Broadcasters have shown support for this utility endeavor and can provide additional value to the utilities by offering on-air timely public awareness of smart grid campaigns along with extraordinary grid service conditions and advisories to the local communities they currently serve. The fact that the electric utility bill is among the highest non-salary line items in an FM broadcast station budget bodes well for a natural symbiotic business relationship with the local utility.

10 Conclusions and Recommendations

1. The Gordian Knot problem of mass consumer device connectivity and “engagement” can best be solved by utilizing broadcasting to unlock the full potential of the smart

grid. The challenge of mass consumer device installation and privacy concerns are best met by broadcasting real time and projected tariffs directly to devices outlined in this paper. The payoffs as highlighted in the results of the SMUD OpenADR-FM broadcasting project are numerous for customers and utilities alike and include quick and efficient deployment of devices, advanced renewable generation, and more realistic real time pricing for TOU and Transactive energy.

2. The calibration and validation of broadcasting can be achieved by
   a. Leveraging existing instrumented lab projects to quantify impact.
   b. Leveraging field pilots at the feeder and substation level with an appropriate number of consumer devices to confirm communications and load shaping efficiencies of the broadcast method.

11 Document References

[1] Herter, K., Wayland, S., Rasin, J. 2009. Small Business Demand Response with Communicating Thermostats: SMUD's Summer Solutions Research Pilot. Prepared for the California Energy Commission, PIER Building End-Use Energy Efficiency Program. Retrieved October 24, 2013, from: http://www.herterenergy.com/pdfs/Publications/2009%20Herter%20(LBNL-2742E)%20-%20Small%20Business%20EEDR.pdf. Page 2.

[2] Herter, K., Okuneva, Y. 2013. SMUD's Residential Summer Solutions Study: 2011-2012. Prepared for the Sacramento Municipal Utility District. Retrieved October 24, 2013, from: http://www.herterenergy.com/pdfs/Publications/2013_Herter-SMUD_ResSummerSolutions2011-2012.pdf. Page 49.

[3] Kgwadi, M., & Kunz, T. (2011). Securing RDS broadcast messages for smart grid applications . *International Journal of Autonomous and Adaptive Communications Systems* , *4* (4), 412-426.

[4] Heffner, G. C., Goldman, C. A., & Moezzi, M. M. (2006). Innovative approaches to verifying demand response of water heater load control. Power Delivery, IEEE Transactions on, 21(1), 388-397.

[5] Parker, G., & GE Appliances (November 30, 2012). Demand Responsive Residential Appliances Interface with the Smart Grid. Retrieved August 21, 2013, from NIST Home to Grid (H2G) Smart Grid Twiki: http://collaborate.nist.gov/twikisggrid/pub/SmartGrid/H2G/DR-Appl2.pdf

[6] Centolella, P. (December 4, 2012). Prices to Devices: A Business Case. Retrieved

August 21, 2013, from NIST Home to Grid (H2G) Smart Grid Twiki: http://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/H2G/P2D-1212.pdf

[7] U. S. Government. (January 3, 2012). USCODE 2011 title16 chap12 subchapII sec824t. Retrieved 08 21, 2013, from U. S. Government Printing Office: http://www.gpo.gov/fdsys/pkg/USCODE-2011-title16/pdf/USCODE-2011-title16-chap12-subchapII-sec824t.pdf

[8] Eustis, C., Horst, G., & Hammerstrom, D. (2007). Appliance Interface for Grid Responses. Retrieved August 21, 2013, from Gridwise Architecture Council: http://www.gridwiseac.org/pdfs/forum_papers/103_106_paper_final.pdf

[9] Wacks, K. (2013). *iHomes and Buildings* Summer 2013 – Transactive Energy for Balancing Smart Grids. Retrieved August 21, 2013, from Continental Automated Buildings Association (CABA): http://docs.caba.org/documents/ihomesandbuildings/CABA_iHomes_summer_2013_web.pdf

[10] National Radio Systems Committee. (1998). Specification of the radio broadcast data system (RBDS). Electronic Industries Association, National Association of Broadcasters.

[11] National Weather Service, NOAA. (2013). NOAA Weather Radio FAQ. Retrieved August 21, 2013, from NOAA Eastern Region Headquarters: http://www.erh.noaa.gov/phi/wxradio/nwrfaq.htm

[12] NOAA Weather Radio (NWR) All Hazards Specific Area Message Encoding (SAME). (2007). National Weather Service. Retrieved October 17, 2013, from: http://www.nws.noaa.gov/directives/010/archive/pd01017012c.pdf

[13] Verizon Wireless. (2013). Verizon Wireless GSA Advantage. Retrieved August 21, 2013, from Verizon Wireless: http://www.verizonwireless.com/pdfs/gsaadvantage.pdf

[14] Singal, T.L. (2010). Wireless Communication. Tata McGraw-Hill. 348-353.

12 About the Smart Grid Interoperability Panel

The Smart Grid Interoperability Panel (SGIP) orchestrates the work behind power grid modernization. SGIP was established to identify technical and interoperability standards harmonization that accelerates modernization of the grid. As a member-funded, non-profit organization, SGIP helps utilities, manufacturers and regulators address standards globally: utilities gain improved regulatory treatment for investment recovery and manufacturers obtain enhanced commercial opportunities worldwide. SGIP members stay competitive, informed and well-connected. To learn more about SGIP, visit http://sgip.org/.