Electromagnetic Compatibility (EMC) Issues for Home-to-Grid Devices

by the

Home-to-Grid Domain Expert Working Group (H2G DEWG)

(Contributors and editors are listed at the end of this paper.)

The primary goal of this paper is to ensure that Home-to-Grid devices address EMC adequately when deployed.

The Situation

The H2G DEWG believes that for the Smart Grid (SG) to deliver benefits it must be reliable, secure, and fault-tolerant. One of the key issues that must be addressed is electromagnetic compatibility (EMC). EMC is the ability to withstand the electromagnetic (EM) environment (sufficient immunity) without causing interference (disturbances) to others.

For Home-to-Grid devices to function properly and to coexist with other electrical and electronic systems in the home, they must be designed with due consideration for electromagnetic emissions from the grid or home and for immunity to various electromagnetic phenomena near the grid or in the home. They must also take into account the devices that are already present in the home to minimize interference to those products. Finally, EMC considerations must take the view that the home and a SG are a system since some issues such as surges caused by sources external to the home (e.g., lightning strikes) cannot be remedied at the end device. Potential approaches to mitigate these effects at the system level are suggested below.

The H2G DEWG asked the IEEE EMC Society for information about EMC. The EMC Society prepared a paper entitled *EMC Considerations in Home-to-Grid Devices*. The H2G DEWG appreciates this contribution; it was useful in developing the positions explained here. The EMC Society outlined four broad categories of EMC events that need to be considered:

1. Commonly-occurring EMC events like electrostatic discharges, fast transients and power line disturbances.

2. RF (radio frequency) interference from various kinds of wireless transmitters.

3. Coexistence with wireless transmitters so that wireless communications can be incorporated beneficially (reliably) into a SG.

4. High-level EMC disturbances, both intentional terrorist acts and naturally occurring events, such as lightning surges and geomagnetic storms.

A Smart Grid and associated components should be designed to be immune to interference from electromagnetic effects to the extent possible and economically feasible. If that immunity fails, they should be fault-tolerant so that failures due to such interference do not lead to systemic disruption. At the same time, the signals used to control the grid should not cause interference to other devices. The U.S. Federal Communications Commission (FCC) regulates emissions from devices in the home in FCC Part 15, which covers both conducted (over the power lines) and radiated (over-the-air) emissions. However, even if those limits have been met, the user must take action to mitigate or to eliminate harmful interference to licensed services such as broadcast TV and radio or amateur radio.

Each of the four broad categories of EMC events identified by the EMC Society is addressed in the following sections.

1. Commonly-occurring EMC events

Manufacturers of Home-to-Grid equipment should consider a variety of electromagnetic phenomena to minimize operational failures or interruptions to Home-to-Grid equipment and systems. A variety of phenomena are known. They include for example, electrostatic discharge (ESD), electrical fast transient (EFT), surge and radiated and conducted RF energy. Inadequate immunity to interference can cause communication or control failures of Home-to-Grid components. Such failures may lead to interruptions of communication to individual loads (e.g., appliances) or a home control system, rendering load devices unavailable for Demand Response events.

Phenomena that may upset a SG can originate from sources located both outside the home and within the home. One of the most important phenomena is lightning, as typical lightning strikes are measured in tens of thousands of amperes, creating large voltage potentials between equipment grounds and utility services (e.g., ground potential of a pool house to main house). Lightning effects on the power grid are well known, and mitigation measures are a normal part of any power grid topology mitigation. However, indirect lightning strikes on the grid, nearby structures, or from nearby ground strikes can cause failures in unprotected communications, control systems, and individual devices within the home.

A. Electrical surges:

Protection from electrical surges should be handled in a four layered approach.

1) The utility or service provider (cable/telephony) provides high-level surge protection “at the service pole.”

2) All wires, both line (AC wiring) and low voltage (cable/telephony, communications/control wiring to outdoor equipment such as pool and gate controls, security systems, etc.) entering or leaving the home should have surge protection, also called whole home surge protection. These first two levels of protection cover electromagnetic effects outside the home with the second also providing protection from high voltage spikes generated within the home.

3) High value devices such as computers, TVs, etc. should have local or outlet surge protection, which may be included in the outlet itself or in an "outlet surge strip"[1]. This helps to eliminate surges from motors (vacuum cleaners, etc.), lighting controls (dimmers, switching), and other in-home sources.

4) The end device should include low-level surge protection, especially in higher value devices that are critical to proper SG operation. However, it should be noted that the primary element used for surge protection has a limited life expectancy based on the number and size of the surges it experiences. Thus, end-device surge protection is not considered a primary solution since the surge protection elements are not field-replaceable. Most entrance, receptacle, and higher quality surge strips include a visual indicator (light) that illuminates when the element needs replacement. These surge protective devices, when integrated with SG equipment, should show a level of robustness that has not been considered in the past by manufacturers.

Note that the first three levels of surge protection lie outside the control of the end-device manufacturer and therefore must be included in either a "best practices" or installation guideline. For high-value devices, testing to a standard such as CISPR 24 or the equivalent is recommended. The levels to test to are variable and depend on the surge environment, which differs from home to grid to power source. Any such recommendations would need to be in an installation guideline or best practices document.

B. Electrical Fast Transients

Electrical fast transients may also propagate on a power line, having originated in switching operations on the lines. These bursts of low-energy, fast rise-time impulses can interrupt or latch-up communications or control signals on the lines, or interrupt equipment connected to the lines. They are very common and very disruptive. Outlet and end-device surge components are used to protect against this form of electromagnetic interference. It is recommended that outlet/strip surge protectors used in a SG installation include such fast transient protection. The rating however must be determined for adequacy.

[1] The surge strips should include ground reference equalization (additional communication ports that tie the service grounds together within the surge protective device).

The installation guideline or best practices document may include recommendations on ratings.

C. Radiated and Conducted Emissions

Unintended emissions (both conducted over the power lines and those emitted into the air) from Home-to-Grid systems have the potential to cause harmful interference to licensed broadcast and communications systems as well as other nearby electronic systems. Limits for these emissions are of critical importance in minimizing the potential for such interference. Limits are specified in the US by the Federal Communications Commission. Methods of measurement to determine compliance with such limits exist and are also specified by the FCC. Note that even when meeting such limits, FCC Part 15 requires that if harmful interference is caused, the user must rectify the problem. This is often accomplished by moving or reorienting the device. However, if it cannot be otherwise rectified, the device must be taken out of service.

Harmful interference is any emission, radiation, or induction that endangers the functioning of a radio-navigation service or other safety services, or seriously degrades, obstructs, or repeatedly interrupts a radio-communication service operating according to the U.S. Code of Federal Regulations (47 CFR, §15.3(m)). Not all interference that may occur is "harmful interference" as defined by national and international regulations. The IEEE P1900.2 Recommended Practice, entitled *Recommended Practice for Interference and Coexistence Analysis* is a good source of additional information on this topic.[2]

D. EMC immunity

Immunity from EMC interference for most consumer electronic products sold in the US is voluntary and driven by market forces. Devices that are found to be unreliable are either redesigned by the manufacturer to fix the problem or are rejected by the consumer or the distribution/retail channel. This is essentially the same as for other non-safety related reliability issues involving poor or inadequate design. If a store or manufacturer gets too many complaints, the product is removed from the market. Warranty repairs, product returns to the retailer/manufacturer, and recall for safety related issues are paths by which defective products are removed from use. Note that consumer smart grid products (H2G) on the home side of a residential meter are non-critical infrastructure. Any immunity testing requirements or testing levels would be based on the criticality (size) of the load/source. These issues are being considered by the Building Subcommittee of the Smart Grid Interoperability Panel Electromagnetic Interoperability Issues Working Group

[2] Information about the scope and purpose of IEEE P1900.2 is available at http://standards.ieee.org/findstds/standard/1900.2-2008.html.

(SGIP EMII WG). However, to help ensure reliability of the Demand Response and metering/billing systems installed, sold, or supplied by a utility for home use, immunity tests such as those defined in CISPR 24 with the proper test levels could be added to Request for Quotations (RFQs) when purchasing SG equipment.

2. Interference from wireless transmitters

Radio-frequency currents on power, communications, and control lines can result from radio transmitters in the environment. These transmitters may be fixed in frequency, power, and location, as is the case for broadcast transmitters and cellular telephone base stations, or they may be flexible in terms of frequency, power, or location relative to the home, especially if they are moved about the home coming close to the SG electronics, e.g., meters. Such transmitters may be mobile police, fire, citizen's band, amateur radio, WiFi transmitters, and various wireless devices in the home. Power levels of such transmitters range from miliwatts, to as much as 5 Watts or more. Fixed transmitters such as higher power amateur radios can radiate as much as 1,500 Watts although the antennas of high power transmitters are typically installed outside the home. TV, AM and FM broadcasters can be as much as 50,000 watts or more, but are required by the FCC to be installed far from user's premises. These transmitters may be modulated using a variety of techniques.

All of these aspects should be examined to determine the appropriate electromagnetic environment for critical Home-to-Grid equipment testing and the criteria and measurement techniques to be used for judging acceptance. In the US consumer electronics devices are not mandated to be immune from interference from these devices. Instead, it is assumed the market will be self-policing as noted above, or the user will move the sensitive equipment to another location. However, for devices critical to the reliable operation of a SG, testing to voluntary immunity standards may be advisable. Again CISPR 24 contains the most used immunity standards for IT equipment. Further, as noted above, utilities providing such devices may wish to include immunity testing and certification to determine compliance as a part of their RFQ process.

3. Co-existence with wireless transmitters

A related issue arises from the intentional use of wireless SG devices in the home. The unlicensed frequency bands are not reserved for the exclusive use of these devices. Any device operating in these unlicensed frequency bands may be exposed to interference from other, unrelated, transmitters in those same frequency bands. Hence, unlicensed wireless transmitters have the potential to cause interference with other equipment.

It should be noted that in-band interference to existing products operating in unlicensed bands in the home (e.g., baby monitors), such as reported in some smart

meter installations, is not an EMC issue. There is no way to guarantee non-interference in such cases. Instead, it is advisable that utilities, smart meter manufacturers, and manufacturers of other non Critical Infrastructure (CI) SG devices choose wireless frequency bands and technologies that are proven to coexist with existing in-home devices. This will serve to minimize consumer backlash and safety issues with, for example, home medical devices by coexisting or not interfering with the use of spectrum already used for these purposes.

Effective planning, supported by appropriate analysis and research, will reduce conflicts among wireless devices (even in different bands when in close proximity) and between wireless and wired devices. Such conflicts could cause disruption of communications and possible failure of important Demand Response or metering/billing functions.

4. High level EM disturbances

High Power Electromagnetic (HPEM) phenomena, which include high-altitude Electromagnetic Pulse (HEMP) created by a nuclear detonation in space, Intentional Electromagnetic Interference (IEMI) caused by electromagnetic weapons used by criminals and terrorists, and Severe Geomagnetic Storms created by solar activity all originate outside the home. While these disturbances may be rare, the damage they can cause to a Smart Grid and to devices within the home is severe including damage to transformers and anything electronic whether it is connected to the grid or not. However, due to the nature of these disturbances, there is little that can be done at the device level or within the home, so we will not delve further into this issue here.

EMC Society Contributors

Stephen Berger	TEM Consulting	stephen.berger@suddenlink.net
Brian Cramer	EISI	bcramer@eisisolutions.com
Andy Drozd	ANDRO	andro1@aol.com
Ed Hare	American Radio Relay League	w1rfi@arrl.org
Don Heirman	Don HEIRMAN Consultants	d.heirman@att.net
Ghery Pettit	Intel Corporation	ghery.pettit@intel.com
Kermit Phipps	EPRI	kphipps@epri.com
Dr. Bill Radasky	Metatech	wradasky@aol.com
Jerry Ramie	ARC Technical Resources, Inc.	jramie@arctechnical.com

Kimball Williams	Denso	kimball_williams@denso-diam.com

H2G DEWG Editors

Dr. Kenneth Wacks	www.kenwacks.com	kenn@alum.mit.edu

Co-chair Home-to-Grid Domain Expert Working Group

Member, GridWise Architecture Council, U.S. Department of Energy

Mike Coop	heyCoop, LLC	mcoop@heycoop.com
Geoff Mulligan	Proto6	geoff@proto6.com
Bill Rose	WJR Consulting	brose@wjrconsulting.com
John Teeter	People Power	john.teeter@peoplepowerco.com