EMC Considerations in Home-to-Grid Devices

preparing for

GridWise Architecture Council / NIST / SGIPGB

by the

Home-to-Grid Domain Expert Working Group

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

The primary statement of this paper is that EMC must be addressed effectively for Home-to-Grid devices to work reliably when deployed.

The Situation

The IEEE-EMC Society Standards Development Committee (SDCom) believes that for the Smart Grid to achieve its potential it must be reliable, secure and fault-tolerant. If the Smart Grid were shown to be less reliable, less secure or less resistant to faults than the current power grid, it would be reasonable to argue that it is not yet ready for deployment. Key among the issues that must be addressed is Electromagnetic Compatibility (EMC), which is the ability to withstand the electromagnetic (EM) environment (sufficient immunity) without causing interference (disturbances) to others. Electromagnetic disturbances of various types from a variety of sources have caused Home-to-Grid (H2G) devices performance degradation, outages and shutdowns.

Cell Phone Turns On Oven (NY Times)


EMC is thus an important factor for consideration in Standards relating to the Smart Grid, including the work in the H2G Domain Expert Working Group. Hence, 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.
There are 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** interference from various kinds of wireless transmitters.

3. Coexistence with wireless transmitters so that wireless communications can be incorporated beneficially (reliably) into the Smart Grid.

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

For all of these categories, the Smart Grid and its components should be designed to be immune, and if that immunity fails, to be fault-tolerant, so that failures do not lead to systemic disruption. At the same time, the signals used to control the grid must not cause interference to others’ devices. Therefore, emissions must be limited whether they are via the power lines (conducted) or over-the-air from nearby sources (radiated).

**EMC Concerns**

Here is a fuller discussion of these four categories of events.

1. **Commonly-occurring EMC considerations**

   Immunity to a variety of electromagnetic phenomena must be demonstrated through testing in order to minimize operational failures or upsets of Home-to-Grid equipment and systems. A variety of phenomena are known. For example, information technology equipment (ITE) used in the home is subject to product immunity tests called out in the IEC/CISPR Publication 24. These immunity tests include electrostatic discharge (ESD), electrical fast transient (EFT), surge and radiated and conducted RF energy. The test levels have to be tailored to be representative of the RF environment where H2G equipment will be located. Inadequate immunity to interference can cause communication or control failures of Home-to-Grid components, leading to interruptions of communication to individual loads (such as appliances), or latch-up of the control system in the home, rendering load devices useless and unavailable for Demand Response events. Consumer backlash would surely follow, similar to what we’ve seen with some smart meter deployments.

   Phenomena that can cause upset to the Smart Grid can originate from a variety of sources. 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. Lightning effects on the power grid itself are well known, and mitigation measures are a normal part of any power grid topology. Communications and control systems included as part of the Home-to-Grid
infrastructure, however, must also be designed to be immune to indirect lightning
strikes on the grid, nearby structures, or from nearby cloud-to-ground strikes.
Lightning strike/surge testing demonstrates the survival potential of home devices
after a thunderstorm. This immunity (survivability) must be demonstrated by testing
to appropriate Standards and levels, and these should be called out in any Home-to-
Grid EMC Standard.

Robustness must be demonstrated on a level never-before anticipated for the Smart
Grid to work. While many standards have been deemed adequate in the past, fielded
equipment failures clearly indicate the need for comprehensive test criteria for
immunity and EMC “hardening.” For example, while some Information Technology
Equipment is tested to IEC/CISPR Publication 24 for immunity to electromagnetic
disturbances to demonstrate reliability, manufacturers of devices used in the US often
choose to avoid immunity testing altogether under the US system of “harmful
interference.” (Devices currently sold in the US may not cause “harmful interference”
but don’t need to be tested for immunity, unless there is a medical safety issue. To
ensure reliability of the Demand Response and metering/billing systems, immunity
tests should be applied as they would be for consumer IT equipment bound for the
European Union, i.e. the “Euronorms” that, in large part, are contained in IEC/CISPR
24. This lack of immunity testing in the US is a real problem, and Home-to-Grid
devices must take this shortcoming into account so that Demand Response or
metering signals are acted upon reliably.

Electrical fast transients may also propagate on a power line, having originated in
switching operations on the lines. These are 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.

Radiated RF energy is all around us and increasing (see the NY Times item on the
previous page). When all those RF fields cut across long conductors, like power lines,
they become conducted RF energy that can easily enter products. Methods and
criteria exist to quantify equipment immunity to these phenomena. Immunity
standards should be used for testing Home-to-Grid equipment to assure reliable
operation in the current omnipresence of RF energy.

Appliance or lighting controls often endure exposure to large power-frequency (60
Hz) magnetic fields from motors or loads, and all environments experience common
power dips and interruptions. These power line effects must not be overlooked in the
design of a power system. Home-to-Grid equipment should be quantified (tested) for
immunity to these common threats.

In addition, 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
(unacceptable) interference to licensed broadcast and communications systems.
Limits for these emissions and proposed measurement techniques to ensure compliance with these limits 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. These should be called out for Home-to-Grid systems used in the US.

2. Interference from wireless transmitters

Radio-frequency currents on power, communication, and control lines 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. Such transmitters may be mobile police, fire, citizen’s band, or amateur radio. Power levels of such transmitters range from 5 Watts or less to as much as 1500 Watts. These transmitters may be modulated using a variety of techniques. All of these aspects must be examined to determine the appropriate electromagnetic environment to simulate for Home-to-Grid equipment testing and the criteria and measurement techniques to be used for judging acceptance.

3. Co-existence of Wireless transmitters

A related issue arises from the intentional use of wireless devices in the home, since the frequency spectra they generally use are not protected (for their exclusive use). Any device operating in these “public” frequency bands has to accept interference from other transmitters in those same frequency bands. Hence, unlicensed wireless transmitters have the potential to cause interference with other equipment, as noted previously (see the NY Times article). However, wireless deployments can be planned to co-exist and even interoperate with other equipment reliably. Without effective planning, supported by appropriate analysis and research, wireless devices can conflict with one another (even in different bands when in close proximity) and with wired devices, causing disruption of communications and failure of important Demand Response or metering/billing functions.

4. High level EM disturbances

The electromagnetic phenomena discussed above are those that occur on a routine basis in the home. Given, however, the planned role of the Smart Grid in operating the national power grid, it is also important to consider additional electromagnetic phenomena that are considered security risks and/or lower-probability risks. There are three high-power electromagnetic (HPEM) threats that are considered in the IEEE EMC Society and for which equipment may be protected. These include the 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. Both the HEMP and Severe Geomagnetic Storms can cause regional power blackouts and permanent damage to large transformers due to the creation of severe harmonics and hot-spot heating. This topic applies primarily to utility-wide disturbances rather than in-home devices, although severe harmonics may simultaneously damage electronic equipment at meters or in homes.

Conclusions

The phenomena we’ve noted above can cause interruptions ranging from momentary, self-correcting malfunctions of individual devices to localized network failures and, in a worst-case scenario, to large scale network interruptions. Interference can be generated naturally, it can be self-generated by the network, or it can come from man-made sources, either unintentionally or intentionally.

The end result is the same – a large-scale power grid or Home Area Network (HAN) that does not reliably function as intended. The Smart Grid can’t “interoperate” if it can’t stay operating. Therefore, appropriate EMC standards need to be referenced by the NIST Smart Grid Interoperability Panel (SGIP) the SGIP working groups.

Summary

It is important to understand the impact of EMC effects on the Smart Grid. The manifestation of physical layer phenomena on Smart Grid operations is a field of study that will be needed to design safeguards properly and to ensure the reliable operation of Home-to-Grid devices.

The IEEE EMC Society wishes to make four key points.

(1) We have the technology to model/simulate and test early in the H2G Program. This will demonstrate the advantages of incorporating EMC up front and cost effectively;

(2) History has shown that the price is high (even to the extent of requiring a major re-design) when EMC is not taken into account as part of early product planning, but is delayed and addressed as an afterthought;

(3) Modern technologies (IT, power, communications, etc.) are very multidisciplinary and require that a synergy of expertise be applied to solve the reliability problem in H2G devices; namely EMC is integral to and of high benefit to the H2G Program as it unfolds and is deployed.

(4) The EMC discipline also helps to underscore the relevant issues of DYNAMIC AND ADAPTIVE SPECTRUM MANAGEMENT and modern interference solutions, where the latter is technical as well as policy-driven. These must be dealt with in a more effective and efficient way than the policy makers and stakeholders allow today.
The members of the IEEE Electromagnetic Compatibility Society (EMCS) are a leading source of expertise in the area of EMC. Members have a wide range of experience and expertise in the overlapping areas of power and EMC, ranging from home-based components to large utility systems, to commercial systems, and to extreme military requirements. The goal of EMC engineers is to design equipment and systems so that EMC issues are minimized or eliminated, as verified by testing. Member of the EMC Society with the appropriate expertise are assisting the H2G DEWG to ensure that Home-to-Grid devices and systems are able to operate reliably in spite of intentional or unintentional interference sources in the intended environment.

We welcome the opportunity to discuss our involvement with those working in the Home-to-Grid program. Our point of contact is the Chairman of the EMC Society Standards Development Committee, Andy Drozd, who can be contacted at adrozd@androcs.com. The URL of the committee is http://www.ewh.ieee.org/soc/emcs/standards/sdcomindex.html.

**EMC Society Contributors**

- Ghery Pettit Intel Corporation ghery.pettit@intel.com
- Dr. Bill Radasky Metatech wradasky@aol.com
- Don Heirman Don HEIRMAN Consultants d.heirman@att.net
- Kermit Phipps EPRI kphipps@epri.com
- Stephen Berger TEM Consulting stephen.berger@suddenlink.net
- Andy Drozd ANDRO andro1@aol.com
- Ed Hare American Radio Relay League w1rfl@arrl.org
- Kimball Williams Denso kimball_williams@denso-diam.com
- Brian Cramer EISI bcramer@eisisolutions.com
- Jerry Ramie ARC Technical Resources, Inc. jramie@arctechnical.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
<table>
<thead>
<tr>
<th>Phone</th>
<th>Name</th>
<th>Company</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>213</td>
<td>Bill Rose</td>
<td>WJR Consulting</td>
<td><a href="mailto:brose@wjrconsulting.com">brose@wjrconsulting.com</a></td>
</tr>
<tr>
<td>214</td>
<td>John Teeter</td>
<td>People Power</td>
<td><a href="mailto:john.teeter@peoplepowerco.com">john.teeter@peoplepowerco.com</a></td>
</tr>
</tbody>
</table>