Electromagnetic Compatibility Issues for Home-to-Grid Devices

by the

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

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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 achieve its potential it must be reliable, secure, and fault-tolerant. One of the key 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.

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 consideration 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 the smart grid are a system since some issues such as surges caused by sources external to the home like lightning strikes, cannot be remedied at the end device. Potential approaches will be suggested below.

As noted in the paper, IEEE EMC Society Standards Development Committee position paper, ***EMC Considerations in Home-to-Grid Devices,*** 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.

The Smart Grid and its components should be designed to be immune to the extent possible and economically feasible, 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 should not cause interference to other devices. Therefore, emissions must be at the very least within regulatory limits whether they are via the power lines (conducted) or over-the-air from nearby sources (radiated). However any "harmful" interference to licensed radio services may require more stringent emission limitations or further separation from the equipment affected.

1. Commonly-occurring EMC events

Manufacturers of Home-to-Grid equipment should consider a variety of electromagnetic phenomena to minimize operational failures or upsets of 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, leading to interruptions of communication to individual loads (such as appliances) or a home control system, rendering load devices unavailable for Demand Response events.

Phenomena that can cause upset to the Smart Grid 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 itself 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. Surge:

Protection from electrical surges is handled in a four layered approach. First, the utility or service provider (cable/telephony) provides high-level surge protection "at the pole". Second, 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 EMC sources outside the home with the second also providing protection from high voltage spikes generated within the home. Third, 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". This helps to eliminate surges from motors (vacuum cleaners, etc.), lighting controls (dimmers, switching), and other in-home sources. And finally, 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 they are not field replaceable. Most entrance, receptacle, and higher quality surge strips include a visual indicator when the element needs replacement, thus indicating when replacement is required.

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 RF environment, which will differ from home to grid to power source. Any such recommendations would need to be in an installation guideline or best practices document.

Immunity from EMC interference for most CE 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 outlet 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 goes off 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. However, to ensure reliability of the Demand Response and metering/billing systems installed, sold, or supplied by a utility, immunity tests such as those defined in CISPR 24 with the proper test levels could be added to their RFQ.

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. 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 generally that which disrupts licensed radio services such as TV and law enforcement frequencies.

2. Interference from wireless transmitters

Radio-frequency currents on power, communications, 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, 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, or amateur radio or even over the air AM, TV and FM signals. Power levels of such transmitters range from 5 Watts or less to as much as 1,500 Watts; TV and FM can be as much as 50,000 watts or more, but are not typically installed in close proximity to the 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 by moving the sensitive equipment to another location. However, for devices critical to the reliable operation of the Smart Grid, 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 of the testing organization to determine compliance as a part of their RFQ process.

3. Co-existence of Wireless transmitters

A related issue arises from the intentional use of wireless devices in the home, since the unlicensed frequency bands 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. However, wireless deployments can be planned to co-exist and even interoperate with other equipment reliably. This is based on a stable situation. Once these devices are moved or a new service in these frequency bands is introduced, new co-existance issues may arise. Guidance to utilities should state that they need to understand the environment and design/specify accordingly to avoid existing users of the proposed RF spectrum. 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.

It should be noted that in-band interference to existing products in the home (e.g., baby monitors) such as reported in some smart meter installations operating in unlicensed bands 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 SG devices choose wireless frequency bands and technologies that avoid interference to existing in-home devices. This will serve to minimize consumer backlash and safety issues with, for example, home medical devices by avoiding the use of spectrum already used for these purposes.

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. However, it is not anticipated that in-home equipment will be able to provide cost-effective protection against such disturbances.

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