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Considerations for the Proper Treatment of Electromagnetic Compatibility (EMC) for Smart Grid Equipment and Systems

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***Abstract*--The authors believe that for the Smart Grid to achieve its potential, it must 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, then it would be reasonable to argue that it is not yet ready for deployment. An important issue 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 to the power grid, from a variety of sources, have caused performance degradation, outages, shutdowns and even large-scale system failures. Hence, for the Smart Grid to function properly and coexist with other electrical and electronic systems, it must be designed with due consideration for electromagnetic emissions from the grid and for immunity to various electromagnetic phenomena near the grid.**

***Index Terms*--Electromagnetic Compatibility (EMC), Electromagnetic Interference (EMI), Electromagnetic Pulse (EMP), Emissions, Immunity, Smart Grid**

I. Introduction

There are four broad categories of EMC events that need to be considered with respect to the Smart Grid:

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 of wireless transmitters so that wireless communications can be incorporated beneficially into the Smart Grid.
4. High-level EMC disturbances, both intentional criminal/terrorist acts and naturally occurring events such as lightning surges and geomagnetic storms.

For these four categories the Smart Grid should be designed so as to be immune, and if that immunity fails, fault tolerant, so that failures do not lead to systemic disruption. At the same time, the signals used to control the grid cannot cause interference to others.

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II. Commonly Occurring EMC Events

Unintended emissions from Smart 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 the limits are of critical importance in minimizing such interference. Limits and methods of measurement exist and should be called out for Smart Grid systems. Immunity to a variety of electromagnetic phenomena must be demonstrated through testing in order to minimize operational failures or upsets of Smart Grid equipment and systems.

A variety of phenomena are known. For example, information technology equipment (ITE) is subject to product immunity tests called out in the IEC/CISPR Publication 24. Substation relaying equipment is covered under IEC 60255-26 and wireless communications equipment under various standards. The immunity tests include electrostatic discharge (ESD), electric fast transient (EFT), surge and radiated and conducted RF energy. Inadequate immunity to interference can cause communication or control failures of Smart Grid components, leading to interruptions of service to individual loads, or wider areas of the grid.

Phenomena, which can cause upsets to the Smart Grid, can originate from a variety of sources. One of the most important phenomena is lightning, as typical lightning strokes are measured in tens of thousands of amperes creating voltage potential differences greater than thousands of volts between equipment grounds and utility services. Lightning effects on the power grid itself are well known, and mitigation techniques are a standard part of any power grid. Communications and control systems included as part of the Smart Grid infrastructure, however, must also be designed to be immune to direct lightning strikes on the grid, nearby structures, and from nearby cloud-to-ground strikes. This immunity must be demonstrated by testing to appropriate standards and should be called out in Smart Grid standards.

Robustness must be demonstrated on a level never before anticipated. 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 most equipment is tested to "ANSI C62.45 Combination and Ring Wave Surge Test," manufacturers often choose to test to the lowest level. However section B.38 of that publication is usually overlooked. To ensure robustness for the power system, environment surges should be applied at a high repetition rate with minimal cool down time in order to demonstrate robustness. This is a real world problem, and Smart Grid components and systems must take this into account.

Fast transients may also propagate on power lines, having originated in switching operations on the lines. These are bursts of low-energy, fast rise-time impulses that can interrupt communication 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 and is increasing. When those RF fields couple to long conductors, they become conducted RF energy. Methods and criteria exist to quantify equipment immunity to these phenomena and they should be used for testing Smart Grid equipment to assure reliable operation in the presence of RF energy.

Utility environments often entail exposure to large power-frequency magnetic fields and all environments experience common power dips and interruptions. These power line effects must not be overlooked in a power system's design, and Smart Grid equipment should be quantified (tested) for immunity to these threats.

III. 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 sites, or they may be flexible in terms of frequency, power and location relative to the grid. Such transmitters include mobile police, fire, citizens' band and 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 Smart Grid equipment testing and the criteria to be used for judging its acceptance.

IV. Co-existence of Wireless Transmitters

A related issue arises from the intentional use of wireless in the Smart Grid. Wireless has the potential to cause interference with other equipment, as noted previously. However, wireless must also be planned so as to co-exist and even interoperate with other equipment effectively. Without effective planning, supported by appropriate analysis and research, wireless devices can conflict, causing disruption of communications and failure of important data transmissions.

V. High-Level EM Disturbances

The electromagnetic phenomena discussed above are those that occur on a routine basis. Given, however, the planned role of the Smart Grid in operating the Nation's 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 Geomagnetic Storms created by solar activity that have created regional power blackouts in the past due to the creation of severe harmonics and reactive power loss in large transformers.

While these may seem to be exotic threats to some, international standards organizations are dealing with protection from these threats with respect to civil equipment and systems. In addition, questions have been asked by Congress (7/21/09 Dept. of Homeland Security hearing) whether these high-level EM threats are being considered in the Smart Grid program. The U.S. House of Representatives has also passed the GRID act in 2010 unanimously to consider these threats to the power grid. When one considers the threats posed by cyber attacks in recent years to the power industry, security is an important consideration.

To deal with the technical aspects of these threats, the IEEE EMC Society, with support from its Technical Committee 5 (HPEM), is developing a standard practice for protecting public accessible computers from EM weapons (IEMI application). Further Cigré has just begun work on protecting substation control electronics from IEMI. Finally the International Electrotechnical Commission (IEC) has been working for 20 years developing a body of standards and reports (20 in all) to protect civil electronic equipment and systems from the threats of HEMP and IEMI.

VI. Conclusions

The phenomena 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 that does not function as intended. The Smart Grid cannot "interoperate" if it cannot stay operating. As such, appropriate EMC standards need to be part of the standards used to develop and operate the Smart Grid.

VII. References

VIII. Biographies