An EMC Implementation Plan for Plant Life Extension

Meeting EMC Requirements for Digital Systems

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Abstract

The integration of digital systems in Nuclear Power Plants has been the subject of much scrutiny for (at least) the last 20 years. In 1997 the NRC commissioned the National Research Council to review the implementation of digital systems in the nuclear environment.[1] It concluded that: "Digital I&C systems offer powerful capabilities that can, however, affect nuclear power plant safety; therefore, digital systems should be treated carefully, particularly in safety-critical applications."

The popularity of plant life extension has led many nuclear plants to consider upgrades of old and obsolete systems and the commissioning of electronic control systems. To meet the requirements specified by the code of federal regulations, new equipment installed as upgrades in existing plants are to be designed to accommodate the effects of environmental conditions and that design control measures such as testing are to be used to check the adequacy of the design. Electromagnetic Compatibility (EMC) is an important environmental and design factor that must be taken into account. NRC Regulatory Guide (RG) 1.180 details the test levels and requirements that are designed to minimize interference and susceptibility of safety-related instrumentation and control equipment in the plant environment. Meeting these requirements represents a major commitment on the part of equipment manufacturers and can be a challenge to complete. Good planning is essential to execute a well-ordered introduction of equipment into the Electromagnetic Environment (EME) of Nuclear Power Plants.

The refueling cycle outage at a nuclear power plant is an opportunity to upgrade obsolete equipment, install upgrades, and commission new systems. As the operating life of plants is extended and as new technology comes available, interference-free operation is a necessity, especially for safety-critical systems. An understanding of the Electromagnetic Environment in nuclear plants is mature, has been well-characterized over the years and numerous standards and test methods developed to test equipment to various stimuli.

Compliance must be demonstrated to a rather comprehensive set of test standards that must be met before equipment can be commissioned. To deal with these requirements, it is necessary to integrate an EMC plan into equipment procurement and development. We call this an **EMC Implementation Plan (EIP)**; the purpose of this plan is to streamline the integration of new equipment into the plant systems and operations.

This article outlines the following elements of an EIP for equipment manufacturers and operators as they develop equipment for upgrades and plant life extension. The principal elements include: Site Survey, EM Evaluation, Equipment Design, and Test Planning & Execution. The objective is to give manufacturers and project teams insight into the proper execution of an EIP.

[1] Digital Instrumentation and Control Systems in Nuclear Power Plants: SAFETY AND RELIABILITY ISSUES. Final Report. National Research Council. National Academy Press. Washington DC. 1997.

The EM Environment

Over the past 15 years the nuclear plant electromagnetic (EM) environment has been mapped, studied and reviewed. The assessment of the environment focus on the two ways that EM energy propagates: Radiation and Conduction. In addition to the *mode* of propagation, the various stimuli that are applied to equipment simulate man-made and natural EM energy and include continuous wave (CW) interference as well as pulsed interference.

Industry, government and the private sector have worked over the past few decades to develop methods of assessment and mitigation aimed at minimizing critical interference occurrences. These efforts have yielded a relatively trouble-free environment, as far as Electromagnetic Interference (EMI) is concerned.

But the EM environment has not remained static.

A profusion of wireless devices have crowded the radio frequency spectrum. Computing, storage, and processing power has become orders of magnitude more complex and measurement methods more exacting. Among the factors that plants can control include siting of transceivers internal to the plant environment (WLAN access points, for example), restrictions on radio use (used for many years) and careful construction and plant layout to avoid coupling between sources and victims of interference.

However, many factors that are beyond the control of plant and project personnel and equipment vendors, but they must be recognized as real potential threats to equipment operation.

I. The Site Survey

The first part of an EIP, particularly for new installations without any history, is the performance of an EM Site Survey. During the mid 1980s the initial studies were undertaken to characterize the EM environment. These studies resulted in the development of two "limits" on emissions: a "plant limit" and an "equipment limit." The plant limit was derived to represent the aggregate of many pieces of equipment operating simultaneously in the same space. The equipment limit has been used in conformance testing of individual systems/devices.

The data, however, were only a sample of a few plants. Additional assurance of proper characterization (i.e., taking additional measurements) is a common practice. These surveys take a few days or a week or two and typically characterize the following EM parameters:

Conducted emissions (30 Hz to 400 MHz (or higher)). The measurement is usually performed using a current probe and spectrum analyzer on incoming power and a sample of the signal cables. A chart showing the measured current (in dB above 1 microampere or dBuA) versus frequency is prepared. The plot may include the plant limit for reference.

Radiated Emissions: Magnetic Field (30 Hz to 100 kHz) The magnetic field ambient measurements are collected using a passive loop antenna connected to a spectrum analyzer. The antenna is physically swept around an area where the new equipment is to be installed. The result is a chart showing dBpT (decibels above one picoTesla).

Radiated Emissions: Electric Field (10kHz to 10 GHz (or higher)) This part of the spectrum is normally where most of the "action" is. As stated before, the profusion of wireless technologies has made rather a clutter of the RF spectrum. In addition, plant managers and operators are extremely nervous about radio transmitters and for good reason. A site survey will employ (usually) several antennae to characterize the electric field in this region of the spectrum. The method is to connect the antenna (perhaps through a pre-amp) to the input of a spectrum analyzer.

Transient Measurements Transient, pulsed sources from intermittent sources (such as lightning and power line faults) may be characterized during this type of survey, but are seldom measured during a site survey. Techniques have been developed to support these measurements where transient issues are suspect.

II. EM Evaluation and Equipment Design

The next step of the EIP is to perform an analysis of the EM data from the Site Survey (if one was performed). The critical element of this analysis is to determine if the plant levels were exceeded. If they were exceeded, then it may be necessary to modify the test levels that would be applied in the third part of the EIP. If the plant emissions are below the plant limit, then there is usually no additional tailoring of the levels.

Whether the test specifications are tailored or not, the prudent next step is to perform a critical review of the equipment design. The elements of this review include the following items:

1. Printed circuit board layout
2. Input AC power review
3. I/O filtering
4. Cable shielding
5. Grounding and Bonding
6. Shielding design, including treatments of ventilation and other apertures

Best-practice of each of the above subjects has filled volumes of books, articles and guidance documents and is beyond the scope of this article. Most EMC design costs **nothing** or next to nothing as more than half of the EMC issues that we witness and tend to in our laboratories involve little more than mechanical or configuration changes.

It is always useful to use a checklist to assess the design and construction of the equipment. An EMC design review should include mechanical, electrical, system and test disciplines. In addition, the review of vendor-supplied test data may be part of this review. For example, a common failure mode is excessive conducted emissions on AC ports. The switched-mode power supply is normally the offending sources in conducted emissions failures; **this simply does not have to be**. The design of compliant supplies is a mature art and it is relatively simple to request data from a vendor that provides conducted emissions data. In addition, other factors, such as the incorporation of surge protection or power factor correction should be evaluated because the Regulatory Guide references tests with a fairly sever surge withstand testing on AC and I/O cables.

When upgrading legacy equipment, a red flag should go up when a vendor promises: “This is just like the last one, which flew through testing with no problems.” It may be true that it looks or performs similarly (functionally), but subtle changes in chassis design, harness, cabling and configuration will make enormous differences in the EMC performance of two “similar” devices. The proof is in the test, but proper attention to the EMC elements beforehand can make the test a step, not a hurdle. We have witnessed as much as 70dB difference in conducted emissions from allegedly identical form, fit and function units.

III. Test Planning and Execution

The final phase of the EIP is to organize and manage the test cycle. Often, the project is under tremendous pressure to finish and slippages in the development process fall into the test cycle. This is often unavoidable, however, and some level of planning should be considered when carrying out an EIP.

The following key considerations should be part of the test planning:

1. Test Readiness
2. Allocation of Internal resources
3. Test vendor selection

Test Readiness

“For want of a nail, the shoe was lost…”

Many test programs have been delayed not for the want of a nail, but the want of a cable or accessory. A proper EIP will work through all the scenarios necessary to execute the test program. Critical issues include providing the proper support equipment, developing software scripts for exercising the product, and making sure the physical arrangement will fit in the lab.

Allocation of Internal resources

It is critical to have personnel available who understand the system’s functionality. In addition, the manufacturer’s support team must understand how the system may behave or respond during susceptibility testing. Have the pass/fail criteria been evaluated? (Pass/fail criteria permitting self-recovery after a transient event may not be acceptable for plant operation – especially safety-related equipment.) Have the person or persons been identified who can make decisions regarding system behavior? Have monitoring systems and methods been defined?

Vendor selection

Selecting a test vendor requires attention to the lab’s equipment and facility capabilities as well as experience in the field. Accreditations to ISO 17025 are an indication that the laboratory’s quality systems and processes have been firmly reviewed by an accrediting body. While accreditation is supportive, it may not be entirely sufficient to qualify a laboratory. A body of work and experience is probably the best method to qualify a laboratory. What references might be available? Have similar systems and programs been performed? What are the credentials of the individuals performing the test? One metric is individual qualifications and certifications. iNARTE is an organization that certifies EMC engineers; vendors with one or more on-staff is a positive indication.

Test results

The equipment qualification test provides the information to assess risk associated with the upgrade. The emissions data confirms that the new item does not emit energy above the applicable limits and the susceptibility (immunity) data confirms that the new item is not vulnerable to interference at defined levels (normally much higher than emission limits to provide a margin between emissions and susceptibility). The susceptibility tests include transient tests with test levels defined in the standard from years of measured data on various facilities. Military or commercial test standards are used to guide the testing. Some plant equipment must be serviced online so qualification testing should be accomplished with service doors and panels open.

Summary

Scheduled outages simply cannot wait for equipment that has not been properly qualified. Forming an EMC Implementation Plan is one method to minimize delays in the delivery and commissioning of new systems and upgrades. Good execution just calls for a bit of good planning.

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Washington Laboratories Ltd is an engineering and test laboratory (https://www.wll.com) providing test, design, and support services for manufacturers and nuclear plant operators who need to meet the stringent EMC requirements of the nuclear environment.