Eliminating the Need for Exclusions Zones in Nuclear Power Stations

PHILIP F. KEEBLER
EMC Group, Electric Power Research Institute
Knoxville, Tennessee, USA

Utilities operating nuclear power plants have been dealing with electromagnetic interference (EMI) problems for over two decades. Many early problems that affected the operation of instrumentation and control (I&C) equipment in plants stemmed from the use of wireless transmission devices (WTDs) (e.g., radio walkie-talkies, cellular phones, etc) inside the plant in the vicinity of system cabinets and cable trays carrying bundles of cables. A simple and partially effective method of reducing EMI events caused by WTDs has been to mark off *exclusions zones* around system cabinets and areas where I&C equipment is installed. The use of these zones has presented some problems for existing plants. For example, some plants have had to expand the area of some zones that became ineffective upon the use of new WTDs that evidently presented an increased risk to the operation and EMI protection of I&C equipment. The sizes of some expanded zones are larger than 2,000 square feet. In addition, some zones encroach upon human traffic areas used by plant personnel to move from area to area within a plant.

Exclusion zones have also been recognized as a problem in the design of new plants. Some plant planners and designers have elected not to use exclusion zones realizing that even a well-planned program designed to limit the use of WTDs in these zones simply presents too high of a risk in causing an EMI event. Success of the exclusion zone strategy depends upon limiting the use of WTDs in those zones. Plant engineers and technicians must be able to use their WTDs in areas close to I&C equipment during maintenance and troubleshooting and possibly even in situations where cabinet doors must be open. Moreover, controlling the inventory of WTDs, especially radio walkie-talkies, will also present problems for plant staff. If radios are categorized by power level, then a plant worker may need a low-power radio when none are available. In this situation, a high-power radio may be the only option available during an emergency situation in the plant.

This article is Part 1 of 2 addressing the issue of exclusion zones in existing plants. Past EPRI research has provided useful guidance in EMC helping to avoid EMI events given the state of plant EM environments in the last 17 years. However, with increasing use of digital I&C equipment in existing plants, the planned widespread use of this equipment in new plants, and the increasing demand to use WTDs in nuclear plants, changing EM environments require the development of new and more effective approaches to manage EMC and the risks associated with EMI events in the plants of today and tomorrow.

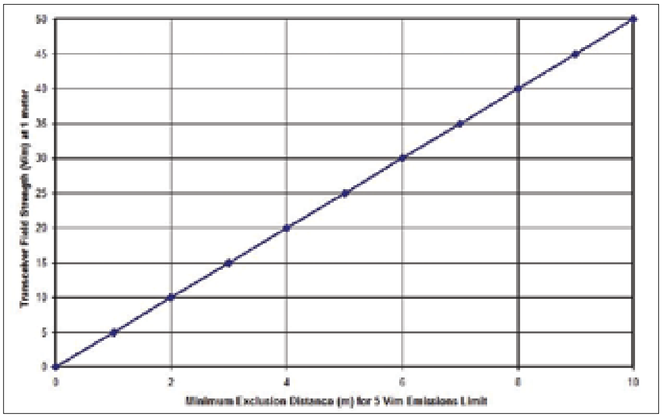

Figure 1. *Recommended minimum exclusion distance (in meters) as a function of transceiver field strength (V/m) at 1 meter. (EPRI TR-102323 (1997) Revision 1).*

BACKGROUND – HISTORY OF EXCLUSION ZONES IN PREVIOUS EPRI REPORTS

Nuclear power plants require a very high degree of protection from EMI. To achieve this, previous guidelines[1] published in a series by the Electric Power Research Institute (EPRI) used a methodology of performing plant electromagnetic (EM) surveys and from that data establishing recommended emissions and immunity levels, tests and EM management strategies. EPRI TR-102323 Revision 1 states in its abstract:

Nuclear power plants undertaking digital upgrades have been required to conduct expensive, site-specific electromagnetic surveys to demonstrate that electromagnetic interference (EMI) will not affect the operation of sensitive electronic equipment. This study was prompted by utilities desiring a more complete understanding of the EMI problem and to provide technically sound alternatives. .... Based on the emissions levels and expected types and levels of interference in nuclear power plants, guidelines for equipment susceptibility tests were developed. ... the levels are conservative based on the analyzed data. The working group defined specifications to obtain additional emissions data to validate these guidelines, develop a basis for equipment emissions testing, bound highest observed emissions from nuclear plants and eliminate the need for site surveys. ..... The report includes minimum EMI limiting practices and guidance on equipment and plant emission levels.

One of the major changes made from the original report by the first revision (Rev. 1) was "an increase of the margin between the allowable plant emissions limit and the susceptibility limit from 6 dB to 8 dB". However, a technical basis is not given in the report for the change. A discussion of the 8 dB buffer is provided in Chapter 7 of that report stating:

The limit for plant emissions was chosen to be 8 dB below the recommended equipment susceptibility testing level ... This limit is selected only to provide a reference point by which the utility engineer may determine if the emissions data from his plant are adequately bounded by the recommended susceptibility testing levels, thus allowing application of the generic susceptibility limits in this report. The plant emissions limit was chosen to be 8 dB below the recommended susceptibility levels to provide additional conservatism in when determining if the recommendations in this report can be applied to a particular facility.

While the reports utilize a strategy of studying plant emissions, and from that and other information, developing a EM protection plan, even in the conclusions of Rev. 1 in that report, the danger of relying too heavily on plant EM survey data is noted.

Operating experience from group members has shown that the nuclear power industry EMI/RFI problems are primarily due to infrequent transient interference and not steady-state EMI. Transient interference is well understood and documented in various industry standards. The industry standards do not require site emissions testing (mapping), but instead define equipment susceptibility testing levels based upon expected maximum plant EMI/RFI levels. Steady-state emissions recorded over a short period of time are unlikely to capture a transient event. The only EMI/RFI emitters that could affect digital equipment operation are portable transceivers. It is reasonable to conclude that steady-state mapping is not useful for identifying threats to digital systems.

Based on an understanding of sources of EMI in nuclear power plants, generic emissions measurements were performed to characterize both steady-state and transient EMI. Procedures were developed to describe the highest observed environment for key safety systems.

What is evident is that while previous versions of the

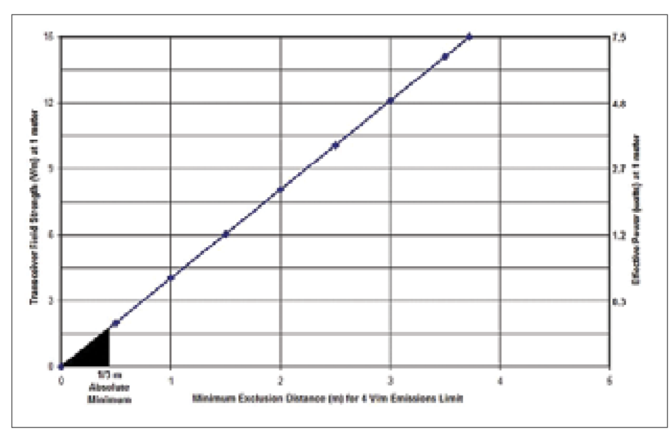

Figure 2. *(Figure 6-1 in EPRI TR-102323 Rev. 2) Recommended minimum exclusion distance (in meters) as a function of transceiver field strength (V/m) at 1 meter. (EPRI TR-102323 (2000) Revision 2).*

[1] *Guidelines for Electromagnetic Interference Testing in Power Plants: Revision 1 to TR-102323-R1*, EPRI, Palo Alto, CA: January 1997.

Guidelines for Electromagnetic Interference Testing of Power Plant Equipment: Revision 2 to TR-102323, EPRI, Palo Alto, CA: November 2000. 1000603.

Guidelines for Electromagnetic Interference Testing of Power Plant Equipment: Revision 3 to TR-102323, EPRI, Palo Alto, CA, and the U.S. Department of Energy, Washington, D.C.: 2004. 1003697.

report gave a central role to data obtained in plant EM surveys, they also recognized the dangers of relying on that data exclusively. In particular, the fact that most interference events occur due to infrequent, transient events was recognized. Guidance solely centered around the statement, “The only EMI/RFI emitters that could affect digital equipment operation are portable transceivers.” must be revised to address the risks posed by the broader availability and use of intelligent WTDs that are appearing in existing plants as well as the ones that will be used in new plants. While certainly portable transceivers are a well identified risk, EMI events caused by the use of today’s modern cellular telephones and other WTDs in the vicinity of I&C equipment present real risks that must be addressed in any plan defining the management of EMC for nuclear plants.

After surveying the data available on plant EM environment, both steady-state and transient, a strategy is recommended for assuring the required level of interference protection. Emissions and immunity levels and tests are recommended for equipment. In order to assure that the immunity levels are not exceeded, the previous versions of the EPRI TR-102323 report recommended the use of exclusion zones to keep electromagnetic and RF sources away from I&C systems. In Chapter 6 of Rev. 1, the following section discusses the method of providing protection from portable transceivers.

Controlling Emissions Sources

Portable Transceivers (Walkie -Talkies)

1. Proper administrative control of portable transceivers is necessary to protect EMI/RFI sensitive equipment. To provide at least 8 dB margin between the transceiver emissions limit (4 V/m) and the recommended equipment susceptibility limit (10 V/m), a minimum transmitter exclusion distance must be maintained. The transceiver field intensity can be estimated knowing the device power level and assuming the highest antenna gain factor of one according to the equation:

$$V_d = \frac{(30\,P)^{0.5}}{d}$$

Eq. 4.1 from EPRI TR-102323 Revision 1

where P is the effective radiated power of the transceiver in watts; d is the distance in meters from the transceiver and Vd is the field strength in volts/meter.

A portable transceiver with an effective radiated power of 3 watts generates a field strength of 9.5 V/m at a distance of 1 meter; 4.75 V/m at 2 meters and 0.95 V/m at 10 meters. The field strength falls of linearly with distance. Alternatively, the transceiver field strength can be measured at 1 meter by testing in accordance with Electronic Industry Standard (EIA), EIA-329 , Part II for Mobile Radios (20).

To determine the minimum transceiver exclusion distance:

1. Calculate the transceiver field strength for a distance, d of 1 meter using Equation 6.1.

2. Referring to Figure 1 (Figure 6-1 in EPRI TR-102323 Rev. 1), determine the minimum transceiver exclusion distance corresponding to the calculated transceiver field strength at 1 meter.

The minimum exclusion distance is required to ensure a margin of at least 8 dB between the transceiver emissions and sensitive equipment susceptibility testing levels. It is acceptable to increase the minimum transceiver distance or to even restrict their use in rooms where EMI/RFI sensitive equipment is located. The group recognizes the need to use these devices and has developed this guidance to support their use where transceivers and EMI/RFI sensitive equipment must operate in a shared environment.

As can be seen by the section title, "Portable Transceivers (Walkie-Talkies)," at the time the report was written the primary concern was walkie-talkies. The report next goes on to discuss arc welding and gives guidance on how to control emissions from that source. The report assumes that the types of portable wireless devices are limited, generally hardware based radios, serving primarily a single function, for practical purposes the only concern was walkie-talkies. For these transceivers, exclusion zones were an effective strategy. Since that time and increasingly, wireless is being utilized in a rapidly growing variety of ways.

Devices increasingly are using digital techniques, controlled by software, in contrast to the traditional hardware-based radios. The trend is more toward multi-function devices that are equipped to transmit on multiple bands using a variety of protocols. Witness the very popular eBook readers, which often are equipped with a cell phone interface, capable of operating on any of several frequency bands, using a variety of RF protocols and in addition have a WiFi radio.

Increasingly, these devices aggressively use power control to maximize battery life. This means that the very same device may operate any of its several radios at different frequencies, using a different protocol and with a wide variation in its transmit power. MIMO (multiple-input, multiple-output) is widely used, allowing some devices to simultaneously transmit on multiple frequencies over any of several antennas. One highly successful smart phone has three different antennas built into its edge.

By the Rev. 2 of the EPRI TR-102323 report, the graph (shown in Figure 2 below) was modified to indicate a 4 V/m maximum emission limit, reduced from the 5 V/m defined in Rev. 1. In addition, a ⅓ meter absolute minimum protection distance was added. The total distance scale was reduced from 10 meters to 4 meters. In addition, a second scale was added to the vertical axis showing the effective radiated power as well as the field strength. While the guidance and verbiage remains relatively the same, these differences indicate a growing need for additional EMC protection while also the difficulty of enforcing a exclusion zone over larger areas.

Figure 3. *An example of an innovative product (electronic book reader) that has an integrated cell phone transmitter.*

The Rev. 3 version of EPRI TR-102323 (2004) keeps the graph unchanged but refines the equation by adding a gain factor:

$$V_d = \frac{(30\,P)^{0.5}}{d}$$

Eq. 4.1 from EPRI TR-102323 Revision 3

While the changes in Rev. 2 and 3 of the EPRI TR-102323 report show a growing sophistication with both threat presented by portable transceivers and the difficulties of effectively implementing and enforcing an exclusion zone strategy, the view of portable transceivers remains relatively constant, with walkie-talkies remaining in the section title for all three revisions.

However, exclusion zones have in some cases failed to provide the required protection and are becoming increasingly burdensome to establish and enforce. This was the consensus, lead by one lead I&C engineer from a major US utility in the south who is currently designing advanced nuclear plants (with one under construction) at the December 2008 EPRI Nuclear EMI Working Group Meeting held in Washington, DC.

Interference incidents which have occurred give evidence to the failure of the exclusion zone strategy to provide the desired level of EMC protection for I&C systems in existing nuclear plants. There are many documented cases of malfunction and upset of I&C systems in existing plants caused by operation of a portable wireless transmission device (not always a walkie-talkie) too close to a standard system cabinet with its doors closed.

At times, the failure is caused a source of EM energy was not recognized as such where an exclusion zone was not involved. One example occurred when the starter for a high intensity discharge (HID) lighting system (magnetically-ballasted) emitted an EM pulse when it attempted to strike a burned out lamp. Because the lamp was burned out, the starter repeatedly attempted to ignite it, emitting a continuing stream of EM pulses as a result. These emissions caused false detections to be registered in a radiation monitor located in another room in the plant. Radiated EM pulses from failed lamps were converted into a band of conducted emissions coupled into the signal loop of the radiation monitoring system. This caused frequent false alarms in the control room.

Another reason for the failure of exclusion zones is that with the increasing use of wireless technology, enforcement of exclusion zones is increasingly problematic. As wireless technologies are adopted and become a more significant part of the work equipment for various personnel, like maintenance workers and security personnel, conflicts are created when enforcement of the exclusion zone would deprive a worker of the tools they rely on to perform their job. This kind of conflict is likely to become increasingly prevalent as wireless technologies are used for an ever increasing variety of functions. Moreover, in today's culture of increased security required to protect nuclear plants and instantly respond to any potential threat, security and plant personnel, any restriction on the use of portable wireless devices will only limit the effectiveness of these personnel to protect the staff and the plant from a possible catastrophic situation. Security personnel must be focused on protecting the plant and staff without having to worry about tripping a critical safety-related I&C system.

The job of an I&C engineer and other plant personnel on the plant floor frequently involves the use of portable wireless devices when the doors of system cabinets are open. Communications are needed with other personnel out in the plant to maintain and troubleshoot I&C systems. Without these communications, standard procedures needed to bring I&C systems back up on line could not be performed.

Additionally, one concern of planners for advanced plants is that use of the exclusion zone strategy will lead to the 'approved use' and 'not approved use' of the inventory of portable wireless devices in the plant. If wireless device began to be segregated based on approval from whether or not they are likely to cause an EMI problem, additional confusion will result when plant personnel strive to manage this divided inventory. One engineering planner was worried that all 'approved' wireless devices would be in use by plant personnel when one was needed. This would result in the selection of a 'non-approved' device for use on the plant floor even though it might be against a plant's policy.

Today, plants are now approving the use of some cell phones and wireless telephones while not approving others. The decision to 'approve' or 'not approve' is sometimes based on misleading information, incorrect test results, incomplete test procedures, or data for the wireless device that may lead plant personnel to suspecting that a device may or may not cause an EMI problem.

Fortunately, exclusion zones are one of three methods for protecting equipment from electromagnetic interference (EMI). Those methods are:

1. Keep unwanted energy out of sensitive I&C equipment by separating the emitting equipment from sensitive

equipment. This is the exclusion zone strategy.

2. Protect sensitive equipment from the unwanted energy by using additional shielding or filtering either at the system cabinet level or inside the cabinet but external to the sensitive equipment.

3. Design sensitive equipment to be inherently immune to the effects of unwanted energy.

In Rev. 3 and earlier versions of EPRI TR-102323, Guidelines for Electromagnetic Interference Testing of Power Plant Equipment, an exclusion zone strategy for dealing with portable transceivers, guided by a simple logic, implemented the first of these strategies.

ADVANTAGES & LIMITATIONS OF EXCLUSION ZONES

Exclusion zones have significant advantages in existing nuclear plants early on when there were fewer portable wireless devices. However, they have also presented a number of sound limitations, which will continue to be used with digital I&C upgrades in existing plants and rolled over to design advanced plants unless a different strategy is taken. Among the advantages of exclusions zones are:

- They are directly controlled by each individual plant.
- They can be customized to the specific needs and conditions in each plant or area of a plant.
- Exclusion zones do not require specialized training or equipment.
- They are not dependent on equipment vendors, outside labs or other external entities.
- They can focus on specific classes of equipment that are problematic.
- Exclusion zones do not increase the cost of equipment or require specialized equipment installation practices.

One of the very real advantages of exclusion zones is that they are directly under the control of each individual plant. A plant is not dependent on an outside entity, such an equipment vendor or test lab. If the exclusion zone fails, it is because the plant where the failure occurred did not enforce it adequately. An exclusion zone can also fail in a sense if its bounded area is too small or if its dimensions are not adequate to provide EMC protection for the expected inventory of portable wireless devices used in a specific plant. Thus, the responsibility to maintain quality control and enforce the exclusion zone rests with the plant, which will suffer the consequences if there is a failure.

A further advantage of exclusion zones is that they can be customized for each individual plant or for specific areas in a plant. For example, if a plant has one area in which the equipment is highly immune to interference, it may not need an exclusion zone in that area at all. However, another plant, using different equipment that is more interference susceptible may require a significant level of protection for a corresponding area. Also, a plant may adjust exclusion zones from time to time, such as relaxing them during maintenance activities, when an area is off-line, or when an I&C system is upgraded to a system thought to be more immune to electromagnetic energy. Exclusion zones offer a high degree of flexibility for local conditions.

Exclusion zones also do not require specialized training or equipment. RF testing is expensive and requires a high degree of expertise to do well. These factors increase the cost of testing and also increase the chance that testing may fall short of what is required. It is not uncommon for testing to be performed with inadequate equipment, by a non-accredited test lab or by personnel who are not appropriately trained and experienced. The use of exclusion zones avoids these issues.

Another advantage of exclusion zones is also an important weakness. If only portable transceivers, especially walkie-talkies are the problem, then an exclusion zone can keep those devices away from I&C systems. This avoids requiring I&C systems take on the cost and complexity of providing significantly higher levels of immunity. If walkie-talkies are the problem, then keeping them away is an effective and efficient solution. How this becomes a weakness will be discussed later, under the disadvantages.

Exclusion zones also have the advantage that they do not increase equipment or installation costs. Requiring levels of RF immunity beyond what vendors are accustomed to will inevitably raise the price of the equipment. The typical pattern is that when vendors are required to meet new requirements they apply quick but inefficient solutions like add-on filtering and shielding not specifically designed for that equipment. Typically, they resort to expensive shielding and filtering. One reason for this is that they seldom have the expertise on staff to develop alternative solutions. It also occurs because they want to avoid the cost of equipment redesign and find a solution that simply protects their existing and typically vulnerable circuitry or equipment.

Over time vendors usually learn how to design equipment that has inherent RF immunity. This kind of solution typically adds little or even no cost to the equipment, but requires considerably more design expertise. This approach is usually introduced as vendors acquire the requisite expertise on their staff and are driven to provide immunity and lower prices by competitive pressures. Design changes may also be introduced to enhance EMC protection after the vendor is made aware of an EMI problem, especially one that ended up costing them money back to the customer. The result is that in the long run requiring higher levels of RF immunity does not inherently raise the cost of the equipment much, but in the short term it typically does.

These advantages of exclusion zones are significant and explain why this strategy was adopted in earlier versions of EPRI TR-102323. It must also be noted that exclusion zones are very amenable to use in a hybrid strategy. Indeed, the EPRI TR-102323 report does not rely exclusively on exclusion zones, but recommends them as part of a

EMI control strategy that includes testing for emissions and immunity. From this viewpoint, the question is not whether exclusion zones should be used or not, but rather is their use, coordinated with other components of a total control strategy optimal for the current and future EM environment that plants will operate in.

The disadvantages of exclusions zones are also significant and well understood by those who are responsible for implementing and enforcing them. These include:

- It can be difficult or even impossible to implement exclusion zones.
- Enforcement of exclusions zones is increasingly difficult and even impossible.
- They are the direct responsibility of each individual plant costing time and resources.
- Exclusions zones can take on different shapes and areas even across plants that use similar designs; there are enough differences in exclusions zones across these plants to create enough differences in the design and implementation of system-wide policies designed to limit the use of wireless transmission devices.
- Exclusion zones often come in conflict with the legitimate need to use wireless enabled technologies to perform necessary job functions.
- Exclusion zones are a product of oversimplifying the problem and as a result are a flawed solution.
- Exclusion zones must use general rules that are often overly conservative.
- Exclusion zones often cannot be fully implemented around I&C systems because of physical barriers (e.g., rails, steps, other equipment) in the way.
- Exclusion zones can extend into areas that must remain clear and walk way areas that must support the heavy traffic of plant personnel.
- Exclusion zones are designed to protect I&C equipment from EM energy emanating from a known inventory of wireless transmission devices (typically portable walkie-talkies). Plants strive to control the use of wireless transmission devices, especially cell phones, owned by contractors and visitors. If these devices are allowed in a plant, then specific exclusion zones may not adequately protect I&C equipment.

Exclusion zones can be difficult or even impossible to implement. They require control of a substantial area around sensitive equipment. However, at times the required protection area is difficult or impossible to control. An example is an I&C system installed near a wall adjacent to an area where it is permissible to use wireless transmission devices, or an external wall, adjoining a parking lot. What radios will be in vehicles entering the parking lot is difficult to control, if it is possible to control them at all with any certainty. Especially when the required protection distance grows to be 3 to 10 meters, it expands beyond the typical room and takes in a significant area. Some exclusion zones take up a very large area of plant floor.

The explosive growth in the use of wireless makes enforcement of exclusion zones increasingly problematic. Wireless devices are now incorporating intelligent decision-making technologies and code making more effective use of unused spectrum. The cell phone illustrated in Figure 3 is an example. Wireless is used in a wider and wider variety of products and applications. It is increasingly difficult to even identify what is a wireless device. Even medical implants are including wireless transceivers, albeit to date those are operating at lower power. How do you enforce an exclusion zone if the transceiver is in an implant inside the body of a plant worker?

When exclusion zones are used, every plant must assign personnel and expend time and effort to implement and enforce them. When a plant elects to use a new wireless technology capable of reaching power levels higher than technologies previously used, new calculations must be made to determine the layout of new exclusion zones. It is not one zone that must be revised but many. (Why should plant personnel strive to keep exclusion zones updated when other more effective strategies can be applied?) This is an ongoing cost, using resources that typically are needed elsewhere. Further, enforcement of exclusion zones is an ongoing responsibility that has potentially significant consequences if there is ever a failure. Enforcement must be ongoing and vigilant to assure that there is never a failure. Assuring such continued vigilance typically requires overly conservative and redundant monitoring to assure continual and effective compliance.

Another problem with exclusion zones is that they regularly create conflicts between the need to protect sensitive I&C systems and the need to use wireless services. The increasing use of wireless for an ever expanding variety of purposes promises to make this kind of problem increasingly common. A worker uses and comes to rely on wireless tools to perform their job but then is told he or she cannot use the tools that have become necessary for their job in the exclusion zone, where they may be required to go to perform maintenance, maintain security or some other job function. These kinds of conflicts occur and create what appear to many as rules without reason.

These kinds of conflicts are exacerbated because exclusions zones must be implemented as general rules, without regard for the differences in wireless services. If, for example cell phones are discovered to cause an EMI problem in a nuclear plant then all cell phones, in all frequency bands and at all power levels must be excluded. However, personnel will often discover that their cell phone creates no interference, making the exclusion zone seem arbitrary and needless. This may lead some plants to issue 'blanket approval' for the use of all cell phones—a strategy that presents undefined risks to the operation of I&C equipment.

The fact is that originally cell phones operated in the 800 MHz band, using RF power of up to two (2) watts. Today, most cell phones still use the 800 MHz band but are also equipped to operate in the 1,900 MHz band, where the maximum power is one (1) watt. Further, the 700 MHz band frequencies have already been auctioned, although equipment has not been deployed there yet. The

Advanced Wireless Services (AWS) band is scheduled to be auctioned, adding frequencies up to 2,100 MHz. Other mobile services are moving forward in the 2,300 MHz and 3,500 MHz bands. The future will see an increasing variety of mobile services, using different frequencies and power levels. Exclusion zones must treat them all equally, not only because most people cannot tell one device from another, but increasingly devices can operate on multiple bands and which band they use is determined dynamically by the network.

A further complication is that cell phones and many other wireless services use very aggressive power control. They only use as much RF power as is necessary to sustain their communications link. Cell phones will vary their RF power by up to 15 dB, a factor of more than 30. The same cell phone in one location, where it has good signal conditions to the network, will operate at 1/30th the power as the same cell phone in another location with poor signal conditions. Exclusion zones must assume the worst and control these devices as if they are operating at maximum power. Indeed, the plant has no control over how much RF power they will use, and it is changing dynamically. So, how is the plant supposed to know if a cell phone provider changes the operation of its network? This could result in changing how the RF power levels are managed. The only option with the exclusion zone strategy is then to be conservative in order to assure the required level of protection.

The use of exclusion zones in existing nuclear plants comes from an analysis that finds portable transceivers, particularly walkie-talkies, to be the only EM threat, so simply keeping them away from I&C systems is an effective and efficient solution. But are portable transceivers the only problem? More specifically are portable transceivers a significantly worse source of EM fields than other sources? If they are, then exclusion zones are an effective remedy.

However, there are many sources of EM fields, both natural and man-made. Can a relatively low level of immunity in I&C systems provide adequate protection against most sources and then by using exclusion zones the more powerful fields from portable transceivers are effectively dealt with? In fact, exclusion zones only give the delusion of protection.

In particular, there are low-frequency, high-impact events that present a rare but important risk category. Two examples of low-frequency events that produce very high levels of EM are Electromagnetic Pulse (EMP) and terroristic use of EM fields. While these events are rare, they are real risks. If they do occur, should nuclear plants be protected against them? Having I&C systems with sufficient immunity to protect against portable transceivers also will increase their ability to withstand EM fields coming from other sources.

IN GENERAL PLANT ENVIRONMENTS

Exclusion zones have been used as an EMC control measure in a variety of plant environments, even those outside of the nuclear power industry. It can be an effective method for controlling EMI. A critical element in the use of an exclusion zone is the degree to which the zone can be controlled. The more reliably an environment can be controlled, the higher the effectiveness of the exclusion zone strategy. As the ability to control the environment is compromised, the effectiveness of the exclusion zone strategy also degrades. So, a fundamental requirement for an exclusion zone strategy to be effective is the ability to control the environment around sensitive equipment. The exclusion zone strategy is not recommended when the area around sensitive equipment cannot be reliably controlled.

Two specific times of plant operation when exclusion zones collapse are when the plant is under unscheduled shutdown and when the plant is under scheduled shutdown. Under unscheduled shutdown, the number one goal of every single plant personnel is to work towards getting the problem resolved and the plant back online. When power is not being generated, money is lost and lots of it. Plant workers simply work without interruption and barriers to aid in getting the plant up and running again. During this time, extremely heavy radio usage takes place. However, not all systems are fully offline. This is absolutely the case in nuclear power plants. Thus, a good number of I&C systems will need to remain online to preserve certain safety functions. Some of these systems may employ the use of exclusion zones.

Under scheduled shutdown, the plant and its personnel are given a fixed number of days to perform the scheduled work (typically refueling). Plant personnel are rewarded for getting the work done and the plant back online early. During this time, certain I&C systems must be functional in order to get the work done correctly and on time. Some of these systems may employ the use of exclusion zones.

The exclusion zone strategy also comes under pressure when competing legitimate interests come into conflict. For the purposes of EMC, an exclusion zone might be desirable. However, there might be very legitimate reasons why wireless equipment should be brought into close proximity to equipment inside an exclusion zone. Maintenance personnel are more effective if they can use their cell phones or walkie-talkies to verify equipment functionality or get needed technical support from another plant engineer. Many exclusion zones are so large that troubleshooting some I&C systems requires the use of three personnel: one at the system cabinet to observe indicators and make measurements, one in the middle of the exclusion zone acting as a ‘repeater’ to deliver the message to personnel outside the exclusion zone so the information can be radioed to personnel in the control room or another area of the plant. Other examples are created when space is limited and different equipment must be put into close proximity, due to its functionality. There are a wide variety of reasons that can arise and put pressure on the use of exclusion zones.

A simple reason exclusion zones are problematic is that real estate inside a plant is in high demand and is generally expensive. Having a lot of unused space in any environment is generally inefficient. Spreading equipment out requires more building space, costing money. Often, the space simply is not available. However, even when space is available, it comes at a cost, usually a high cost. Mapping out an exclusion zone for a specific I&C system may permanently mark that area as unusable for any other function.

For these reasons, the use of exclusion zones is increasingly rejected. Planners engaging in digital upgrades in existing plants and in specifying digital equipment for advanced nuclear plants do not want to see exclusion zones in their plants. Other methods of EMC control are found more effective. Shielding, filtering or improved immunity, but implemented at the right level, are increasingly the preferred methods for EMC control.

IN ADVANCED NUCLEAR PLANT ENVIRONMENTS

The disadvantages of exclusion zones become increasingly relevant when considering the environments of advanced nuclear power plants. Looking to the future, the use of wireless for communications, data transmission and sensor networks is a growing reality. The ability to exclude these services from areas were I&C systems operate is not only increasingly problematic but also undesirable. Indeed, some I&C systems will greatly benefit from wireless connectivity, for example, to distributed sensor networks. The ability to enforce an exclusion zone will be a growing problem as wireless is integrated into an ever increasing variety of equipment types. Therefore, a different method for providing the required level of protection is required.

CONCLUSION

This article, Part 1 of 2 on the topic of exclusion zones and their strategies in nuclear power plants, presented a history of the development and use of exclusion zones originally defined by EPRI research in the area of EMC for nuclear power plants. Early strategies served their purpose in a time when wireless devices were few. Moving towards a more effective strategy for protecting digital I&C equipment from radiated threats in plant environments requires an understanding of the advantages and disadvantages of exclusions zones as presented in this article. Effective and dynamic protection of digital I&C equipment against radiated threats must be an inherent part of I&C systems allowing plant engineers to focus on plant safety, operation, maintenance, and upgrades without the challenges presented by the use of exclusion zones. Nuclear power plants are facing more challenges, and those that can be resolved providing a higher degree of safety and reduced risk will help utilities maintain safe plants that are profitable. Part 2 of this article will address Elements of the Exclusion Zone Strategy with a focus on peeling back the layers of immunity for I&C systems to establish whole-system immunity.

BIBLIOGRAPHY

- [1]. Guidelines for Electromagnetic Interference Testing in Power Plants, EPRI TR-102323, Rev 1, Electric Power Research Institute, Palo Alto, CA, 1996.
- [2]. Guidelines for Electromagnetic Interference Testing in Power Plants, Revision 2 to EPRI TR-102323, TR-1000603, Electric Power Research Institute, Palo Alto, CA, 2000.
- [3]. Guidelines for Electromagnetic Interference Testing in Power Plants, Revision 3 to EPRI TR-102323, TR-1003697, Electric Power Research Institute, Palo Alto, CA, 2004.
- Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems, Regulatory Guide (R.G.) 1.180, U. S. Nuclear Regulatory Commission, 1996.

***Philip F. Keebler** manages the Lighting and Electromagnetic Compatibility (EMC) Group at EPRI where EMC site surveys are conducted, end-use devices are tested for EMC, EMC audits are conducted and EMI solutions are identified. Keebler has conducted System Compatibility research on personal computers, lighting, medical equipment, and Internet data center equipment. The lighting tasks were associated with characterizing electronic fluorescent and magnetic HID ballasts, electronic fluorescent and HID ballast interference, electronic fluorescent and HID ballast failures, and electronic fluorescent and HID lamp failures. Keebler has drafted test protocols and performance criteria for SCRP tasks relating to PQ and EMC. He served as editor developing a new EMC standard for power line filters, IEEE 1560.*