Electromagnetic and Radio Frequency Interference (EMI/RFI) Considerations For Nuclear Power Plant Upgrades

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Presented to:

Presented by:
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SC-2
Presentation Topics

- Define Electromagnetic Compatibility (EMC)
- Identify the three components of an EMC problem
- Myths Surrounding EMC
- EMC Best Practices
- Standards Used for EMC Qualification
- Wireless Technology Considerations

<table>
<thead>
<tr>
<th>Point Form</th>
<th>Integral Form</th>
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</thead>
<tbody>
<tr>
<td>$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$</td>
<td>$\vec{B} \cdot d\vec{I} = \oint (\vec{A} + \frac{\partial \vec{D}}{\partial t}) \cdot d\vec{S}$ (Ampère's law)</td>
</tr>
<tr>
<td>$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$</td>
<td>$\vec{E} \cdot d\vec{I} = \oint (-\frac{\partial \vec{B}}{\partial t}) \cdot d\vec{S}$ (Faraday's law; $S$ fixed)</td>
</tr>
<tr>
<td>$\nabla \cdot \vec{D} = \rho$</td>
<td>$\int_{V} \vec{D} \cdot d\vec{S} = \int_{V} \rho , dv$ (Gauss' law)</td>
</tr>
<tr>
<td>$\nabla \cdot \vec{B} = 0$</td>
<td>$\int_{S} \vec{B} \cdot d\vec{S} = 0$ (nonexistence of monopole)</td>
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</table>
What is Electromagnetic Compatibility?
EMC is Comprised of Two Parts

• **Emissions**
  How much electromagnetic energy a device generates

• **Immunity**
  How much electromagnetic energy a device can withstand
## EMI Terminology

<table>
<thead>
<tr>
<th>COMMON DESCRIPTION</th>
<th>FORMAL DESCRIPTION</th>
<th>COMMON CAUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonics</td>
<td>Conducted Low Frequencies</td>
<td>Non Linear AC Loads, Inverters</td>
</tr>
<tr>
<td>Surges</td>
<td>Surges</td>
<td>Direct or Indirect Lightning Strikes, Power Faults</td>
</tr>
<tr>
<td>Spikes</td>
<td><strong>Electrical Fast Transients/Bursts</strong></td>
<td><strong>De-energizing Inductive Loads, Switch Arcing</strong></td>
</tr>
<tr>
<td>Electrostatic Discharge</td>
<td>ESD (Electrostatic Discharge)</td>
<td>Movement Between Insulator and any Other Material</td>
</tr>
<tr>
<td>RF (Radio Frequency)</td>
<td>Radiated Electric Fields</td>
<td>Radio Transmission, Spark Gaps</td>
</tr>
</tbody>
</table>
What Is An EMC Issue?

1. System or equipment that is a source (Aggressor) of the Interference
2. System or equipment that is susceptible (Victim) to the Interference
3. Coupling (Path) conducted or radiated

Must have all three components for EMI to occur

**Aggressor**
- Arcing
- Power Faults
- Lightning
- Transients
- Radiation
- Microprocessor
- SMPS
- Digital

**Conductive**

**Capacitive**

**Inductive**

**Wave Propagation**

**Susceptible Victim**
- Instrumentation
- Controls
- Communications
- Low level analog
- Digital
Myth 1: Noise Takes Path of Least Resistance

SIGNAL GENERATOR

50 Ω Terminator

Copper Wire – 3 inches; 3 mΩ

Coaxial Cable – 10.5 feet; 153 mΩ
Where does Current Flow?

Cable Length – 10.5 feet; 153 mΩ
Short section – 3 inches; 3 mΩ
Video: Resistance vs. Impedance
Myth 2: Cable Routing is Not Important

Proper Filtering

- Separation of Input and Output

Improper Filtering

- Input and Output Tie-Wrapped Together

120 VAC Power → Power Line Filter → DC Power Brick → Laptop
Effect Of Tie-Wrapping Cables Together

Nearly 50 dB of attenuation reduced to only 18 dB

Graph showing the effect of filtering on cable attenuation:
- No Filter
- Improper Filtering
- Proper Filtering

Amplitude (dBμV) vs. Frequency (Hz)
- 10 kHz to 1 MHz
- 18 dB reduction
- 30 dB reduction
Separation is Critical

Dance Floor

HEAD TABLE

CAKE

GIFTS

BAR

RESTROOMS

KITCHEN
Input and Output Power Tie-wrapped Together
EMC Best Practices Can Prevent Most EMI Issues

• Power Line Filters
  – At the cabinet boundary

• Maintain Twisted
  – With GND Wire for Power

• Power and Signal Cable Separation
  – Cross at 90°
  – Separate Cabinet Entry

• Shield Bonding
  – Short Leads
  – EMI Reference

• Ground
  – Follow Safety Codes
  – Follow EMI Practices

• Do not tie-wrap cables
EMC Can Be Simplified If You Treat It Like A Program

- EMC does not begin and end with qualification testing – Think of planting a seed in a garden

- It takes an EMC program
  - Understand EMC
  - Know the Requirements
  - System Design
  - Construction and Wiring
  - Qualification Planning and Testing
  - System Installation
  - Future Maintenance and Troubleshooting
Standards Used for EMC Qualification

• Nuclear Regulatory Commission (NRC)
  – Regulatory Guide 1.180 Rev 0,1

• Electric Power Research Institute (EPRI)
  – Topical Report TR-102313 Revisions 0,1,2,3,4

• International Electrotechnical Commission (IEC)
  – 62003:2009

• Military Standards
  – MIL-STD-461 E,F,G

• International Standards
  – IEC 61000
  – CISPR
IEEE 603

- Defining Electromagnetic Environment
  - IEEE 473 and MIL-STD461E

- Evaluation of EME
  - Conductive, Radiative, Inductive, Capacitive

- EMC Testing
  - EPRI TR-102323, MIL-STD461E, IEC Tests

- System Design for EMI
  - Shielding, grounding, routing, suppression, filtering, data quality checks, software techniques
Addressing the Implementation of Wireless Technology

• **Existing Approach**
  – Qualify new equipment and establish exclusion zones
  – Adequate for fixed devices
  – Challenge to address mobile devices

• **Future Approaches**
  – Qualify new systems to higher levels at frequencies of interest
  – Test systems in-situ against wireless signals
EMC is NOT Rocket Science

• Understand what to look for and how to find it

• Simple design considerations can address most EMI issues

• Select the appropriate tests for the equipment to be installed
A 3-Day Training Course on
EMC Fundamentals for the Nuclear Industry

- Electromagnetic Compatibility Concepts
- Electric and Magnetic Field Coupling
- Transients and Electromagnetic Waves
- Shielding
- Principles of Grounding
- Design Considerations to Control EMI
- EMI Troubleshooting
- EMC Qualification Testing
- NRC Regulatory Guide 1.180
- EPRI TR-102323

The course will include both class lectures and hands-on demonstrations.

Register today to lock-in an early bird rate of $1500!

For more information, please contact Kayla Poland at kayla@ams-corp.com
Thank You!

Questions?