ELECTRIC POWER RESEARCH INSTITUTE

Equipment Electromagnetic Compatibility (EMC) Analysis and Studies

Annual Update 2007

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PRODUCT DESCRIPTION

The substation presents a unique combination of critical and sensitive equipment embedded in a very harsh electromagnetic interference (EMI) environment. Electromagnetic noise is naturally generated by the normal operation of relays, disconnect switches, and circuit breakers in high voltage substations. Substations that incorporate flexible AC transmission systems (FACTS) and high voltage DC (HVDC) converters can create additional high frequency EM noise that may interfere with the operation of control systems and nearby electronic devices.

Electromagnetic compatibility (EMC) deals with the ability of electrical devices or components to operate correctly in the presence of varying degrees of EMI. Unfortunately, particularly in North America, standards for substation EMC are often inadequate. In addition, the innovative technologies now being applied to substations require a constant evolution of EMC standards; and standards tend to lag behind technological development by several years. This report addresses these problems by summarizing EPRI work on equipment EMC and providing an update on anticipated technological developments.

Results & Findings

This annual update summarizes prior EPRI deliverables that focus on the EMC impact of new technologies and provides an update on anticipated technological developments.

Challenges & Objectives

Substation designers and operators using these tools will be able to reduce the risk sometimes associated with the application of new technologies. Use of these tools will result in less down time, reduced capital and operating costs, and increased system reliability. While all substations will benefit from this work, it is particularly relevant to substations where new solid-state power devices and digital electronic control and communication devices are being installed.

Applications, Values & Use

A variety of valuable new technologies are coming to substations. These include solid-state current limiters and transformers, microprocessor-based controllers in countless applications, and wireless condition monitoring. These and other technologies can be made to work without EMI problems, but success requires prior planning and a commitment to incorporating EMC into the design of the systems.

EPRI Perspective

While there are technical committees around the world that address substation EMC standards, their efforts take many years and the resulting maze of standards is difficult to understand. EPRI is uniquely positioned to act as an advocate for electric power companies in the area of substation EMC and the impact of new technologies. EPRI's network of international members and contractors allows it to draw on the greatest possible resources and to identify the best practices for EMC.

Approach

EPRI staff reviewed existing deliverables, EMC standards, and technology development activity as they apply to best practices for substation EMC in the design and operation of substations.

Keywords
Substation
Standards
Electromagnetic Compatibility
EMC
Electromagnetic Interference
EMI

ABSTRACT

The substation presents a unique combination of critical and sensitive equipment embedded in a very harsh electromagnetic interference (EMI) environment. Unfortunately, standards for substation electromagnetic compatibility (EMC) are often inadequate, particularly in North America. The problem is made worse because the application of innovative technologies to substations requires a constant evolution of EMC standards, but the standards tend to lag behind technological development by several years. This report addresses this situation by summarizing EPRI work to date on equipment EMC and providing an update on anticipated technological developments. This information will allow designers and operators of substations to specify EMC requirements that will improve equipment and substation reliability and facilitate the application of advanced technologies and systems.

ACKNOWLEDGEMENTS

This report includes a summary of prior deliverables that, together, comprise a significant contribution to the industry. These acknowledgements apply to this entire body of work, and would be incomplete without recognition of all the individuals and organizations that contributed to the EMC Program. Since a detailed listing would be longer than the report itself, a list of categories of supporters and contributors will have to suffice:

- Member Utilities
- Industry Technical Associations
- National and International Standards Organizations
- Outside Contractors
- Volunteer Contributors, Proof Readers, and Editors
- EPRI Technical Staff
- PDM Sector Staff and Management
- Environment Sector Staff and Management
- EPRI Technical Publications Staff
- And, the families of all those who worked late into the night to meet deadlines and insure that the best possible products are made available to our industry.

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1
INTRODUCTION

For several years, the EMC Program within EPRI's Power Delivery Sector (and before that EPRI's Environment Sector) has been providing members with the tools needed to understand substation EMC (electromagnetic compatibility) issues, measure and manage substation EMC, and implement substation EMC audit programs. This annual update summarizes those prior deliverables focusing on the impact of new technologies, and provides an update on anticipated technological developments.

2
EQUIPMENT EMC DELIVERABLES

The following is a listing of EPRI's prior substation EMC Deliverables with brief descriptions of each:

Generic EMC Deliverables

Power System Electromagnetic Compatibility, 2000, 1001049

- Introduction of EMC/EMI for power company personnel, including the EMI effects of defective equipment as well as equipment functioning as intended. Resource Paper.

An Introduction to Electromagnetic Compatibility Standards, 2002, 1005494

- Increase energy providers' awareness of EMC standards, explain power equipment testing requirements, and enhance installed reliability of equipment. Resource Paper.

Customer EMC Brochure, 2004, 1008711

- This brochure assists energy company personnel in discussions with concerned residential and commercial customers. Technical Update.

The Potential Impact of the Power System on GPS (Global Positioning System)

Study of the Potential for Electric Power Facilities to Affect Use of the Global Positioning System (GPS), 2000, TR-1000085

- Interference with basic GPS microwave-frequency satellite signals is unlikely. A number of potential interference sources from both electric power facilities and other electrical devices have the potential to affect lower frequency differential signals. Technical Report.

The Nationwide Differential Global Positioning System and Electric Power Line Interference, 2001, 1005206

- A study of the potential for interference with the nationwide differential GPS signals, and potential mitigation. Technical Brief.

Evaluation of the Potential for Power Line Carrier (PLC) to Interfere With Use of the Nationwide Differential GPS Network, IEEE Transactions on Power Delivery, Vol. 17, No. 4, October 2002

- Peer Reviewed Paper.

The Potential Impact of FACTS Equipment

Electromagnetic Compatibility (EMC) Evaluation of Flexible AC Transmission System (FACTS) Technology and High-Voltage, High-Power Switching Devices – Workshop Minutes and Appendices, 2001, TR-1105220

- Evaluates research requirements, reviews user problems and testing, and lays the ground work for EPRI FACTS EMI testing. Technical Report.

Low-Frequency Electromagnetic Field Measurements Near FACTS Devices, 2002, TR-1005486

- Provides measured 60 Hz and harmonic field levels near FACTS devices. Compares those levels with various standards for occupational and non-occupational exposure. Technical Report.

Electromagnetic Interference Emission Measurements Near FACTS Devices, 2003, TR-1007753

- Provides measured RF field levels near FACTS devices. Investigates reports of equipment malfunction associated with EMI from FACTS devices. Determines that systems can be installed with minimum EMI if proper attention is given to radiated and conducted EMI in the design of the installation. Technical Report.

Substation EMC Standards

Substation EMC Standards, 2004, 1008707

- A full assessment of existing and proposed substation EMC standards. Technical Report.

Substation EMC Standards: Volume 2, Further Discussion and Proposed Changes, 2005, 1011662

- This report pulls together existing standards from around the world, together with proposed changes to these standards. Through a series of tables, substation personnel are able to identify appropriate standards for various substation equipment and systems. Technical Report.

The Substation of the Future

EMC in Transmission and the Substation of the Future, 2004, 1008708

- This report examines the Substation of the Future and anticipates the impact that new technologies and practices could have on electromagnetic compatibility. Major considerations are power electronics, electronics in relaying and control, wireless technologies, and reduced spacing of equipment. Technical Update.

Substation Equipment EMC: Analysis and Studies, 2005, 1010557

- This report describes testing of a next generation solid-state power device and an analysis of the potential for increased emissions. Substation design action items are provided, and future research needs are reviewed. Technical Update.

Measuring and Managing Substation EMC

Measuring and Managing Substation EMC, 2004, 1008709

- Translates the prevailing standards – particularly IEC international standards – into a set of guidelines for asset owners. Measurement procedures, equipment, and practices for evaluating relaying equipment are explained. Technical Update.

Measuring and Managing Substation EMC: Non-Relaying Equipment, 2005, 1010744

This report explains how EMI should be measured in substation environments, providing substation operators the tools they need to maximize electromagnetic compatibility. Technical Update.

3
DEVELOPING TECHNOLOGIES

Foremost among developing technologies that could impact substation EMC is the progress in solid-state power electronics. Power electronic devices are in development with the capacity to carry higher current, at greater voltage, and with significantly faster rise and fall times. This is important to those concerned with EMC because each of these performance enhancements has the potential to increase electromagnetic emissions.

Increases in current result in higher levels of magnetic fields. Increases in voltage result in higher levels of electric fields. And, faster rise and fall times result in higher frequency emission. Figure 4-1 shows the highest frequency of emissions produced by different technologies of solid-state power electronic devices. (Switching power results in a broad frequency spectrum of emissions. These are the highest frequencies expected in each case.) The data points shown at the lower left of the graph are from existing technologies of solid-state power electronic switches. The data point at the upper right is from a new technology in development. Observing the frequencies of emissions that can result from operation of these devices, it is clear that harmonics are not the major concern. With emissions at 63 MHz, and greater, the RF emissions must be addressed.

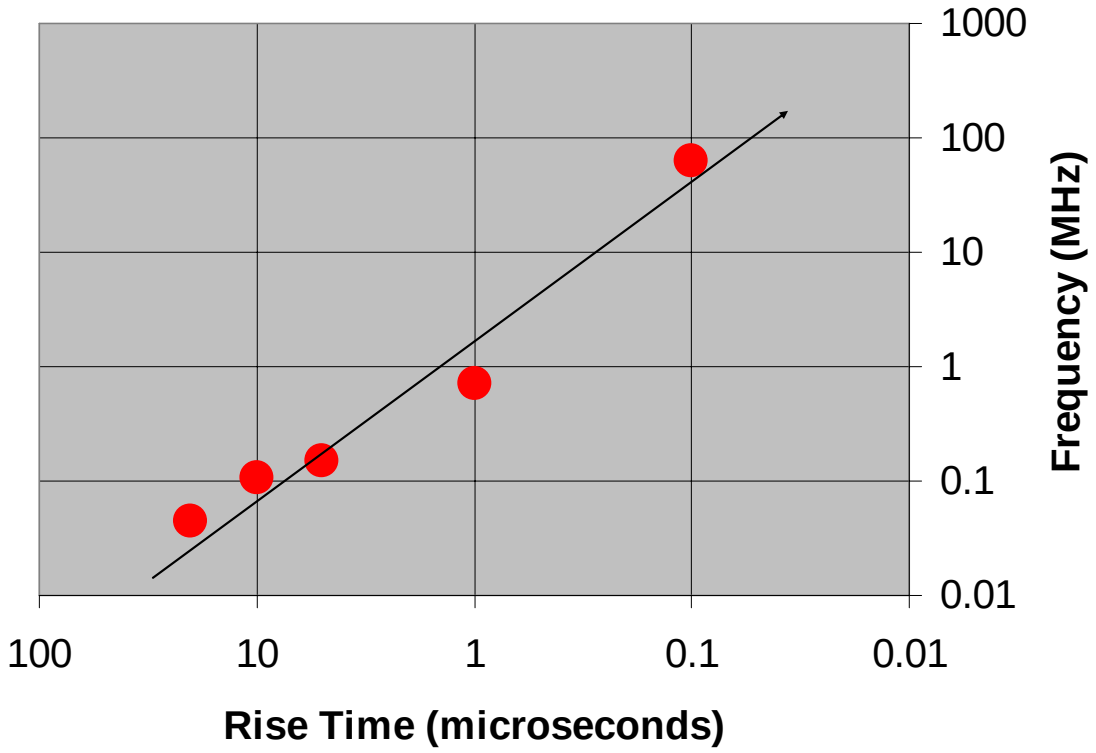

Figure 3-1
Highest Frequency vs. Rise Time

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