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Substation EMC

Annual Update 2007

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Technical Update, November 2007

EPRI Project Manager

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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 (EM) noise is naturally generated by the normal operation of relays, disconnect switches, and circuit breakers in high-voltage (HV) substations. Substations that incorporate flexible AC transmission systems (FACTS) and high-voltage DC (HVDC) converters can create additional high-frequency (HF) 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, 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 summarizes EPRI work on substation EMC and provides an update on standards development from around the world.

Results & Findings

This annual update summarizes prior EPRI deliverables pertaining to substation EMC issues, including measuring and managing substation EMC and implementing substation EMC audit programs. The report also summarizes Technical Standards Committee activity and lists changes in relevant EMC Standards.

Challenges & Objective(s)

Substation designers and operators using these tools will be able to reduce risk sometimes associated with 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, it takes many years to get results, 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 standards. Our network of international members and contractors allows us to draw on the greatest possible resources and to identify the best practices for EMC.

Approach

EPRI staff reviewed existing deliverables and standards, summarized technical committee activity, and reviewed changes to these standards 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. Additionally, innovative technologies being applied to substations require a constant evolution of EMC standards. These standards tend to lag behind technological development by several years. This report summarizes EPRI work to date on substation EMC and provides an update on development of standards from around the world. This information will allow designers and operators of substations to specify EMC requirements that will improve equipment and substation reliability and facilitate 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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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 these prior deliverables and lists changes in relevant EMC Standards.

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SUBSTATION 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.

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EMC STANDARDS COMMITTEES

Within the scope of work for EPRI's EMC Program, under Project Set 167B, EPRI staff have participated in several national and international standards committees. Brief summaries of these committees and their recent activity are listed here.

CISPR 18

Work was begun in 2007 on the next revision of CISPR 18, *Radio Interference Characteristics of Overhead Power Lines and High-Voltage Equipment*. This work is conducted under CISPR Subcommittee B, Working Group 2. CISPR 18 has three parts:

1. Description of Phenomena
2. Methods of Measurement and Procedure for Determining Limits
3. Code of Practice for Minimizing the Generation of Radio Noise

The kick-off meeting was held in YongPyong, South Korea on July 13th and 14th, 2007. The meeting attendees were:

- Bernd Jaekel (Siemens): bernd.jaekel@siemens.com
- Brian Cramer (EPRI): bcramer@epri.com
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- Heesung AHN (KESRI): sagaahs@snu.ac.kr

The committee laid out the scope of the revision and the timetable for the work. Major areas to be addressed include:

- Reference Distance (direct distance of 20m -> lateral distance of 15 m)
- Absolute Noise Limit (SNR -> Noise Values)
- Prediction Formula (Summarized Table)
- Addition of Catalogues (154, 345, 765 kV)
- Consolidation of Amendment Including New Information e.g. CIGRE 36-01 Guide

- Consolidation of Some Amendment to Main Document
- Revision of Normative Reference, e.g. CISPR 16

The potential changes to CISPR 18 could have an important impact on some power line operations. Perhaps the greatest impact could be on Broadband Over Powerline (BPL) systems (a.k.a. PLC or Broadband PLC).

The current timetable projects publication of the revised standard in 2009.

IEEE 1775

IEEE 1775 is working on the initial release of the *Standard for Powerline Communication Equipment – Electromagnetic Compatibility (EMC) Requirements – Testing and Measurements Methods.* This committee has met many times over the last three years to draft the standard for BPL system emissions and immunity testing procedures. A Task Force of that Committees (TF4) is currently working to resolve initial comments provided by a select group of twelve experts who were nominated by the Power Engineering Society (4), the Electromagnetic Compatibility Society (4), and the Communications Society (4). The draft standard is expected to go to full ballot in a few months.

The outcome of efforts such as P1775 can have a major impact on electric power companies by clearing the way for – or impeding the implementation of – BPL and other new technologies. Participation in efforts such as P1775 is critical for the electric utility industry.

AREMA COMMITTEE 38

Committee 38 of the American Railway Engineering & Maintenance-of-Way Association (AREMA), called the Information, Defect Detection & Energy Systems Committee, addresses issues including interference from ac power systems. As co-sponsors of the EPRI *Power System and Railroad Electromagnetic Compatibility Handbook,* AREMA Committee 38 has played a vital role in the process of improving the ability of power systems and railroads to share joint rights-of-way. Committee 38 is tasked with the responsibility of maintaining that portion of the *Railroad Signal and Communication Manual of Recommended Practice* that pertains to the potential for electrical effects on railroad systems.

Sub-Committee 2, Electromagnetic Compatibility, is currently involved in the revision of several manual parts pertaining to railroad signal equipment immunity from electromagnetic interference.

The successful cooperation between electric utilities and railroads begins with AREMA Committee 38.

CIGRE SC C4

CIGRE is the International Council on Large Electric Systems. The aim of CIGRE is described on their web site as:

> "CIGRE (International Council on Large Electric Systems) is one of the leading worldwide Organizations on Electric Power Systems, covering their technical, economic, environmental, organizational and regulatory aspects.
>
> A permanent, non-governmental and non-profit International Association, based in France, CIGRE was founded in 1921 and aims to:
>
> - Facilitate and develop the exchange of engineering knowledge and information, between engineering personnel and technical specialists in all countries as regards generation and high voltage transmission of electricity.
> - Add value to the knowledge and information exchanged by synthesizing state-of-the-art and world practices.
> - Make managers, decision-makers and regulators aware of the synthesis of CIGRE's work, in the area of electric power.
>
> More specifically, issues related to planning and operation of power systems, as well as design, construction, maintenance and disposal of HV equipment and plants are at the core of CIGRE's mission. Problems related to protection of power systems, telecontrol, telecommunication equipment and information systems are also part of CIGRE's area of concern."[1]

CIGRE Study Committee SC C4 is called, "System Technical Performances". The Mission of SC C4 is: "To facilitate and promote the progress of engineering and the international exchange of information and knowledge in the field of System Technical Performance. To add value to this information and knowledge by means of synthesizing state-of-the-art practices and developing recommendations."

Advisory Group C4.2 of SC C4 is called, "Electromagnetic Compatibility". Brian Cramer of EPRI is a corresponding member of C4.2. There are two Working Groups and three Task Forces under AG C4.2. They are:

- WG C4.2.01 : "EMC HV Substations and Generating Stations" (P. Pretorious)
- JWG C4.2.02 : "EMC with Communication Circuits LV Systems and Metallic Structures" (L.E. Juhlin)
- TF C4.2.03 : "ELF Field Measurement and Modeling" (F. Deschamps)
- TF C4.2.04 : "Magnetic Field Mitigation Techniques" (E. Salinas)
- TF C4.2.05 : " Characterization of Magnetic Fields Levels" (J. Hoeffelman)

[1] www.cigre.org

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EMC STANDARDS DEVELOPMENTS

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. Additionally, innovative technologies being applied to substations require a constant evolution of EMC standards. These standards tend to lag behind technological development by several years.

The EPRI report *Substation EMC Standards: Volume 2, Further Discussion and Proposed Changes*, 2005, 1011662, provided a detailed explanation of the national and international standards that apply to electric power substations and the equipment used in them. Since that report was published two years ago, several of the proposed standards that were listed in the report as under revision have been published, and others are in revision. The following is a listing of relevant standards that have been released or updated in the last two years:

FCC 47CFR 15 (Part 15)

> "Part 15" applies to unintentional radiators and limits the RF emissions such devices may create. The most significant change is that the FCC has removed the "harmful interference" protection from mobile use of 2-way radio. All other limits, and "harmful interference" protection from fixed operators, remain unchanged. This change came about in response to interference caused by BPL (broadband over powerline) systems with mobile amateur radio operations in the HF bands.

EN 55011, 2007

> *Industrial, scientific and medical (ISM) radio-frequency Equipment. Electromagnetic disturbance characteristics. Limits and methods of measurement*.

EN 55022, 2006

> *Information technology equipment. Radio disturbance characteristics. Limits and methods of measurement*.

IEC 61000-3-2, 2006

> *Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).*

IEC 61000-4-3, 2006

> *Electromagnetic compatibility (EMC). Testing and measurement techniques. Radiated, radio-frequency, electromagnetic field immunity test*.

IEC 61000-4-5, 2006

Electromagnetic compatibility (EMC). Testing and measurement techniques. Surge immunity test.

IEC 61000-4-12, 2006

Electromagnetic compatibility (EMC). Testing and measurement techniques. Ring wave immunity test.

IEC 61000-4-18, 2006

Electromagnetic compatibility (EMC). Testing and measurement techniques. Damped oscillatory wave immunity test.

IEC 61000-6-2, 2005

Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments.

EN 60255-22-1, 2005

Electrical relays. Electrical disturbance tests for measuring relays and protection equipment. 1 MHz burst immunity tests.

IEC 61326-1, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. General requirements.

IEC 61326-2-1, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. Test configurations, operational conditions and performance criteria for sensitive test and measurement equipment for EMC unprotected applications.

IEC 61326-2-2, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. Test configurations, operational conditions and performance criteria for portable test, measuring and monitoring equipment used in low-voltage distribution systems.

IEC 61326-2-3, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. Test configuration, operational conditions and performance criteria for transducers with integrated or remote signal conditioning.

IEC 61326-2-4, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. Test configurations, operational conditions and performance criteria for insulation monitoring devices, according to IEC 61557-8 and for equipment for insulation fault location according to IEC 61557-9.

IEC 61326-2-5, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. Test configurations, operational conditions and performance criteria for field devices with interfaces according to IEC 61784-1, CP 3/2.

IEC 61326-2-6, 2006

Electrical equipment for measurement, control and laboratory use. EMC requirements. Particular requirements. In vitro diagnostic (IVD) medical equipment.

CISPR 11, 2006

Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement.

CISPR 16-1-1, 2007

Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus.

CISPR 16-1-2, 2007

Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Conducted disturbances.

CISPR 16-2-1, 2007

Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements.

CISPR 16-2-2, 2007

Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-2: Methods of measurement of disturbances and immunity - Measurement of disturbance power.

CISPR 16-2-3, 2007

Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements.

CISPR 16-2-4, 2007

Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-4: Methods of measurement of disturbances and immunity - Immunity measurements.

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