# Substation EMC Standards: Volume 2

## Further Discussion and Proposed Changes



*Technical Report*

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Further Discussion and Proposed Changes

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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, the innovative technologies now being applied to substations require a constant evolution of EMC standards; and standards tend to lag technological development by several years.

This report pulls together existing standards from around the world, together with proposed changes to standards, to provide substation designers and operators the tools they need to maximize electromagnetic compatibility.

### Results & Findings

The report provides a series of tables that allow substation personnel to identify appropriate standards for various substation equipment and systems. The report also presents issues that go beyond existing standards including a discussion of proposed changes to standards that new technology may require. This information will allow designers and operators to specify EMC requirements that will improve equipment and substation reliability and facilitate the application of advanced technologies and systems.

### 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, it takes many years to get results, and the resulting complex 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. Its network of international members and contractors allows it to draw on the greatest possible resources and to identify the best practices for EMC.

## Approach

Top experts from around the world came together to review existing standards, summarize and discuss proposed changes to these standards, and evaluate best practices for substation EMC in the design and operation of substations. This team then produced tables that will be used to develop EMC specifications for 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 technological development by several years. This report pulls together existing standards from around the world, together with proposed changes to these standards, to provide substation designers and operators the tools they need to maximize electromagnetic compatibility. Through a series of tables, substation personnel will be able to identify appropriate standards for various substation equipment and systems. Additionally, issues that go beyond existing standards are presented along with proposed changes to standards that new technology may require. This information will allow designers and operators to specify EMC requirements that will improve equipment and substation reliability and facilitate the application of advanced technologies and systems.

# ACKNOWLEDGMENTS

We thank the EPRI contractors who contributed their unique skill and technological ability. We also deeply appreciate the help of the EPRI utility participants who provided financial support.

We owe special thanks to members of various technical committees around the world for their inputs regarding standards development and their editorial assistance.

While various standards are referenced in this report, it is imperative for the reader to understand that to implement any of these standards, the user must purchase and comply with the latest version of each standard.

And finally, as an industry, we need to acknowledge the continuing efforts of the volunteers around the world who participate in the development of EMC standards through technical committees. Without these dedicated professionals our task would be insurmountable.

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# 1
# INTRODUCTION

The substation environment with its large currents, high voltages, and the operation of circuit breakers, disconnectors, and switches makes it an especially severe 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, including flexible AC transmission systems (FACTS) and high voltage DC (HVDC) converters, can create 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.

The substation presents a unique combination of critical and sensitive equipment embedded in a very harsh EMI environment. In spite of the magnitude of EMI levels in substations and the important nature of its operation, the complementary issues of EMI and EMC are sometimes regarded in the electric power industry as more of a nuisance than as essential components in promoting substation reliability.

Volume one of this report [1] discussed substation EMC research and summarized how well existing EMC standards represent the substation environment. This report identifies the pertinent U.S. and European standards and best practices for addressing EMC applicable to high voltage substation operation and presents a summary of changes to existing standards under consideration by European and U.S. technical committees (TC) and working groups (WG). In addition to presenting background and technical detail, this report is designed to be a practical guide in applying EMC standards to the procurement and installation of substation equipment (see *How to Use this Report*, page 3-1).

# 2
# THE IMPORTANCE OF EMC

Why is EMC important for the substation designer and engineer? Consider the following:

- The FCC requires that EM emissions from substations do not cause “harmful interference”; that is, emissions must not endanger the functioning or seriously degrade, obstruct, or repeatedly interrupt a communications system. In an example cited below, noise sources on a 14 kV feeder caused harmful interference to aircraft communications at a nearby airport requiring corrective action by the power company.
- In Europe, all products that produce emissions or may be affected by EMI are subject to emissions limits and immunity requirements.
- Any HV or high-current switching device generates EM emissions in a broad spectral range. This includes load break switches and solid-state devices such as FACTS systems.
- Microprocessor-based equipment is more susceptible to EMI; therefore, EMC will become more important with time as control and sensor equipment are upgraded with more EMI sensitive microprocessor-based electronics. Trends in the power industry show an increased incorporation of microprocessor-based technology.
- Substation designers and integrators are responsible for purchasing equipment that must operate in that environment. Consideration of EMC ensures effective implementation of new technologies and improves their reliability. The section *How to Use this Report* on page 3-1 outlines how this report can be used to consider EMC in substation equipment purchases and operation.
- Problems caused by EMI are often spurious and intermittent in nature making them particularly difficult to diagnose. The actions required to retrospectively correct such a problem can require extensive re-engineering of an installation.
- It is invariably more cost effective to design equipment from the outset with EMC as a major design criterion rather than to try and add EMC features retrospectively to correct a problem.

## Is the EMI/EMC Problem Real?

Instances of equipment failure or significant interference with communications systems over the past several years have been traced to EMI-related causes:

- Interference from spark discharges on the power distribution system interrupted aircraft communications with the tower at a county airport along the landing path. Three sparking noise sources on a 14 kV feeder (due to loose hardware) at a road intersection outside the airport boundary and just below the landing path were identified and repaired. The interference disappeared after the repairs were completed.

- Handheld radios in the frequency range from 150 – 1000 MHz caused the misoperation of in-service solid state and microprocessor power system relays. In one specific instance, a 470 MHz handheld radio caused a substation relay contact to close resulting in a transmission line interruption. Laboratory tests indicated that this effect occurred when the radios were as far as 10 feet (3.05 m) from the relay.
- EMI generated by fast solid-state switching devices within a FACTS caused that system to drop off line by interfering with the control circuits. In another example, interference from a FACTS coupled energy into a power line carrier (PLC) communication system that prevented the remote substation from seeing the drop in the carrier level, resulting in loss of coordination of circuit breaker operation during a fault.
- Naumov and Vukelja [2] reported that substation EMI was responsible for decreased reliability of signaling devices and the malfunction of electronic protection and communication equipment. Particularly during switching operations, common mode conducted interference set up false signals in protection circuits.
- Meininger [3] cited an example of a lack of EMI considerations during the design phase of a system resulting in interference that was solved only when the existing system was replaced. In this case, a microprocessor controller had to be replaced after implementation of several remedial measures did not eliminate all problems.
- EMI generated by the operation of a particular disconnector in a substation resulted in a generator 500 meters (1640 feet) away in the adjacent power station tripping. This was found, after a lengthy and expensive investigation, to be caused by incorrect grounding of the generator control electronics.
- Uglesic et al. found that busbar protection malfunctions were due to EMC problems. The source was AIS disconnector switching associated with 123 kV GIS [4]. Disconnector switching operations generated common mode currents flowing on the outside of GIS bus-ducts causing interference and eventually busbar protection to malfunction.
- Carsimarmovic et al. investigated switching overvoltages from 220 kV AIS to determine the levels leading to relay tripping, signaling equipment malfunctions, and the burning of supply unit protection relays [5]. Disconnector operations generated interference currents that through conducted interference developed unwanted differential mode voltages in secondary circuits.
- A static compensator (STATCOM) was installed using insulated gate bipolar transistor (IGBT) devices. Upon initial operation, several IGBT devices failed each day. Root cause analysis showed that the IGBT devices failed because of false triggering, and that the false triggering had two causes. The gate control circuits in this facility were provided by a new subcontractor. These circuits were less immune to EMI than previous units. And, electrostatic discharges (ESD) at the connections between fiber optic cables and the gate units also caused false triggering. Once the control circuits and fiber optic couplers were modified, the IGBT failures stopped.

EMC standards provide a tool for designers and integrators to assess whether new equipment or configurations will work properly and as required in the substation environment. As power delivery systems evolve toward more automated and “smart” systems, they will incorporate a wide range of new technologies and designs. Increased reliability and reduced costs can be ensured by paying attention to potential EMC problems. For example, wireless sensing networks can be installed at a fraction of the cost of conventional sensing devices but may be more susceptible to EMI. Many problems encountered in implementing such a system can be avoided by ordering components that meet substation EMC standards and by consideration of the impact of emissions from the sensors themselves.

## The High Voltage Substation Environment

High voltage substations can be divided into two environments: a primary environment and a secondary environment as illustrated in Table 2-1.

**Table 2-1**
**Primary and Secondary Environments of a High Voltage Substation**

| **Substation Environments** | |
|---|---|
| **Primary Environment** | **Secondary Environment** |
| HV Busbars | AC & DC circuits (low voltage) |
| Disconnectors | Control circuits |
| Breakers | Supervisory circuits |
| Ground electrode | Auxiliary circuits |
| Transformers | Alarm circuits |
| Capacitors | Communication circuits |
| Cables | Ground network |

The *primary environment* refers to the HV environment and contains all HV equipment and associated parts: the HV busbars and cables, primary circuits of instrument transformers and all equipment operating at high voltage. Also included in the primary environment is the substation ground electrode, all equipment grounds, bushing capacitances and stray capacitances to ground. The primary environment in this context further extends to include all secondary cables (including those in trenches) inside the HV yard and outside the control room.

The *secondary environment* contains sensitive electronic equipment that may include circuits for power (AC or DC), auxiliary, supervisory, alarm, protection, control, communication, and the ground network. The secondary environment in this context excludes secondary cables enclosed by the boundaries of the primary environment.

The term *control room* (also known as the control building or control center) is used in a general sense and refers to the enclosure or building housing; for example, the battery room, the carrier room and the relay room in a substation. The control room may also refer to protection bay kiosks.

Traditionally, an artificial boundary is introduced between the two environments which can be realized on site as the brick wall constituting the control building. However, with the increasing integration of control and supervisory circuits throughout the substation, the distinction between the primary and secondary environments is becoming characterized by function rather than by location within the substation. For example, solid-state sensors, traditionally considered as part of the secondary environment, are being installed on equipment in switchyards. Another example is high power FACTS devices located in control buildings.

## Unique Features of the Substation EM Environment

A particularly relevant feature of the substation environment is the relatively rapid evolution of equipment in the secondary environment. In contrast, technical advances and turnover of primary environment equipment occurs relatively slowly compared to secondary environment equipment. For example, disconnectors used in modern air insulated substations (AIS) are similar in design to the disconnectors built and used in the sixties. No major change in disconnector design has taken place in close to forty years; they still interrupt capacitive currents through large air gaps. Thus, no significant changes are expected in relation to the high emission levels this equipment generates.

More significant changes and developments, on the other hand, are occurring in the control, protection and communication technologies housed in control rooms over the past forty years. For example:

- Phase II protection (an electro-mechanically based technology) is steadily being replaced by Phase III and Phase IV protection (microprocessor-based technologies).
- Power line carrier (PLC), an analogue based technology, being paralleled by wireless supported communication and optical fiber systems (digitally based technologies).

The successful introduction and operation of these newer microprocessor-based technologies in the harsh substation EMI environment requires that the technology be immune to such interference. Equipment used in a substation typically requires compliance with Level 2 or Level 3 EMC specifications. Designing, developing and testing equipment that is electromagnetically compatible with this environment places high financial demands on the developer and eventually on the end-user.

## The Structure of EMC Standards

In the United States, electronic equipment is subject to American National Standards Institute (ANSI) and International Special Committee on Radio Interference (CISPR) standards while equipment sold in Europe is tested according to the product standard for industrial process, measurement, and control (IPM&C) equipment, IEC 61326-1 and the IEC 61000 series. The more severe EM environment of power and substations motivated the development of IEC Standard 61000-6-5 to specify additional tests designed to simulate that environment.

EMC standards deal with two kinds of interference effects:

- Interference transmitted along wires (conducted),
- Interference transmitted through space (radiated).

Emissions tests measure what the product generates during operation whereas immunity tests measure the effect of EMI imposed on the product. Conducted and radiated effects apply to both emission and immunity tests. For example, an EM conducted emissions test measures the RF noise voltages the device transmits through cables connected to it while an EM radiated emissions test measures the RF "leakage" and re-radiation from wires.

In the United States, the concept of "harmful interference" is applied against CISPR limits for Conducted Emissions and Radiated Emissions testing. Products must withstand external interference and operate safely, and must not cause harmful interference.

In Europe, products that produce emissions or may be affected by EMI are subject to EMC Directive 2004/108/EC. The Directive specifies "Essential Requirements" in which products do not disturb radio, telecommunication systems, or other products and have adequate levels of immunity to interference to operate as intended.

The development of the European directives, in particular the EMC Directive, has led to the development of three kinds of standards: *Product Standards* (or product family standards), *Generic Standards* and *Basic Standards*. Only Generic Standards and Product Standards are considered to be *harmonized standards*.

- **Product Standards:** These define specific EMC requirements and tests for products in the scope of the standard. They normally do not include detail measurement methods which are referenced in the basic standards. They do include limits and detail related to performance criteria.
- **Generic Standards:** These define the EMC requirements, including limits, and indicate the standard tests (Basic Standards) applicable to products intended for use in a specific environment. They include general performance criteria associated with specific test levels and are used in absence of any harmonized product standards.
- **Basic Standards:** These define specific test and measurement methods, equipment and test set-up for specific types of disturbances and may include ranges of test levels but do not prescribe limits or performance criteria.

Generic standards apply where no product standards are available. IEC 61000-6-5 presents, for example, the generic standard for immunity for power station and substation environments. No corresponding IEC generic emission standard for these two environments exists at present, pointing to the challenge facing the EMC engineer in terms of which universal standards should be used for compliance testing.

## The Structure of EMC Organizations

In Europe, several organizations are involved in the development of emission standards:

- The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies.
- The International Council on Large Electric Systems (CIGRE) focuses on electric power systems, covering their technical, economic, environmental, organizational and regulatory aspects. CIGRE is not a standard-setting organization but plays an important role by contributing to the knowledge developed and used in and by standard-setting organizations.
- The International Special Committee on Radio Interference (CISPR) is a special committee under the sponsorship of the IEC addressing aspects related to radio interference. CISPR standards are oriented primarily toward EM emissions and EM measurements although immunity issues are also considered.
- The European Telecommunications Standards Institute (ETSI) is an independent non-profit organization whose mission is to produce telecommunications standards relevant today and in the future.
- The European Committee for Electrotechnical Standardization (CENELEC) is a non-profit technical organization that prepares voluntary electrotechnical standards to help develop the Single European Market/European Economic Area for electrical and electronic goods and services.

Technical committees (TC), working groups (WG), and study committees (SC) debate the merits of new tests or changes to existing tests and submit them to their respective organizations for review. Once a consensus is reached on the submission, it is taken up by CENELEC for further review and eventual adoption as a European Standard (EN) (see Figure 2-1).

In the United States, the Institute of Electrical and Electronics Engineers (IEEE) working groups and technical committees propose new standards and standard changes to the IEEE at large. These are then submitted to ANSI for ratification as an IEEE/ANSI standard (see Figure 2-2).

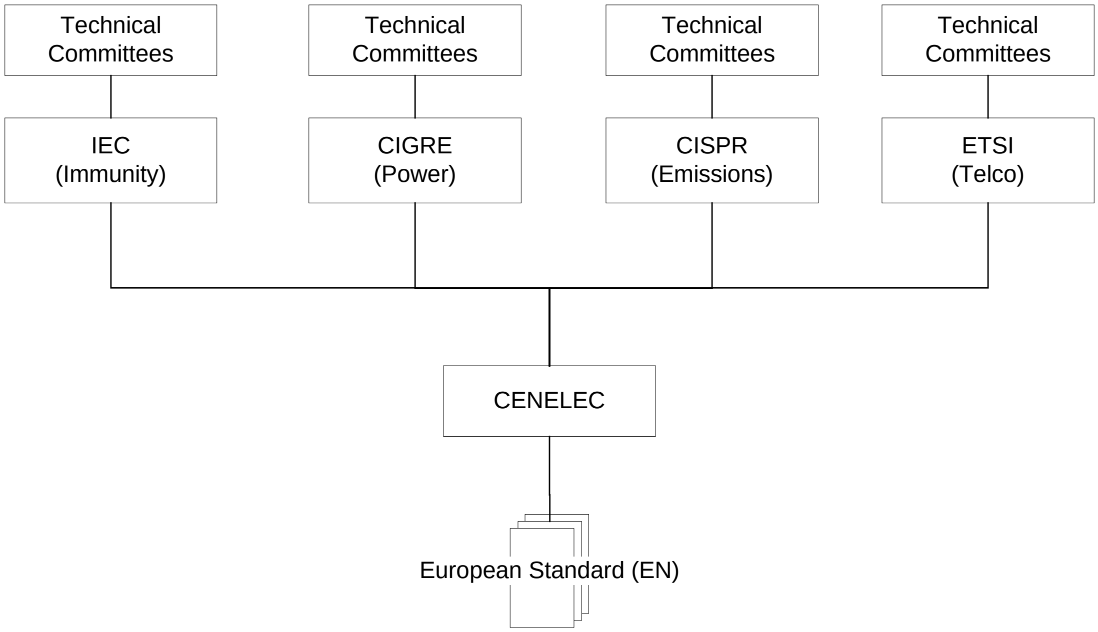


**Figure 2-1**
**European Standards Organizations**

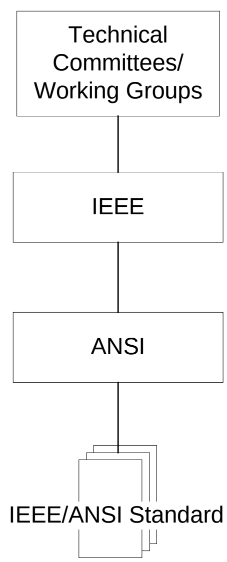


**Figure 2-2**
**United States Standards Organizations**

# 3

# HOW TO USE THIS REPORT

This report is designed to provide practical guidelines in applying EMC standards and practices to substation equipment. This section provides a general outline to using the tables in this report and applying EMC considerations in procuring and installing electronic substation equipment (see Figure 3-1).

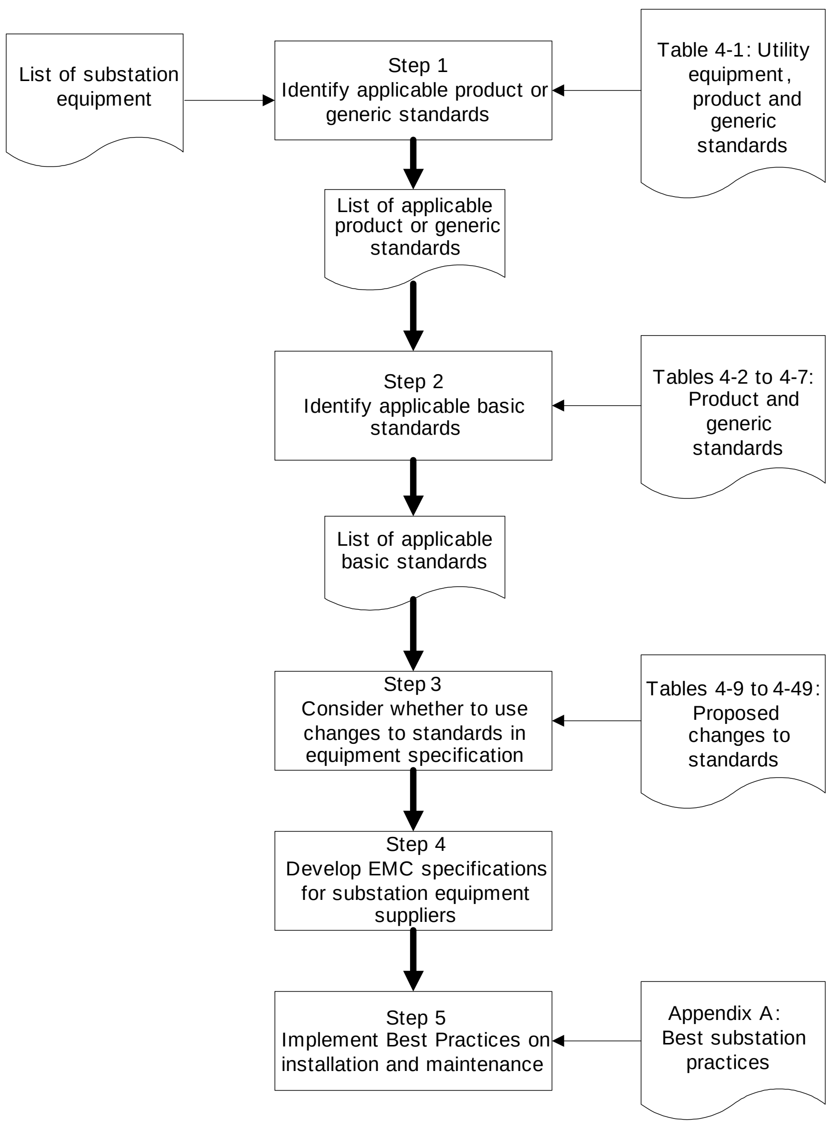


**Figure 3-1**
**Flowchart – How to Use this Report**

**Important** The complexity of the substation EM environment makes it impossible to guarantee that EMI-related problems will be eliminated by following these standards. However, following this process will greatly reduce the risk of failure and the malfunction of substation equipment and processes caused by EMI.

Do the following for all equipment considered for installation in the substation:

### Step One: Identify the Applicable Product or Generic Standards for the Equipment

In Table 4-1 (page 4-2), identify the equipment type under which the item falls and find the applicable EMC *product* or *generic* standards (see *The Structure of EMC Standards*, page 2-4). For example, a FACTS device falls under the *Other substation equipment* category because it is not tele-control, relaying, or switchgear (the available product standards). According to the column heading in Table 4-1, the relevant EMC product standard for this equipment category is IEC 61000-6-5.

**Important** Industrial process, measurement, and control (IPM&C) equipment and information technology equipment (ITE) such as sensors, PCs, and test equipment are not designed for the substation EM environment. The authors strongly recommend that IPM&C and ITE equipment intended for use in substations pass the IEC 61000-6-5 generic standard for “other substation equipment” (see Note 1 in Table 4-1).

### Step Two: Identify the Basic Standards for Each Applicable Product or Generic Standard Identified in Table 4-1

Each product and generic standard listed in Table 4-1 is composed of specific basic EMC standards. The Table 4-1 column headings are cross-referenced to other tables listing the basic standards. Using the FACTS example, IEC 61000-6-5 is cross-referenced to Table 4-4, *Generic Standard for Substation Equipment*. This table lists the applicable basic emissions and immunity standards for different types of EMC tests (such as conducted, radiated, power line, etc.):

- EN 55022 for conducted emissions
- IEC 61000-4-6 for conducted immunity
- IEC 61000-4-3, IEEE C37.90.2, and IEEE PC37.90.2/D6 for radiated immunity
- IEC 61000-3-2 and IEC 61000-3-3 for power-line emissions
- IEC 61000-4-8, IEC 61000-4-11, IEC 61000-4-16, IEC 61000-4-17, and IEC 61000-4-29 for power-line immunity
- IEC 61000-4-2 and IEEE PC37.90.3/D2.3 for ESD immunity
- IEC 61000-4-4 and IEEE C37.90.1 for EFT immunity
- IEC 61000-4-5 for surge immunity
- IEC 61000-4-12 and IEEE C37.90.1 for surge withstand immunity.

## Step Three: Note the Basic Standards Under Review for Change

The basic standards listed in Table 4-2 through Table 4-7 that are under review for changes are marked with an asterisk (*) and cross-referenced to tables describing the changes in detail. These changes may be motivated by the technologies in the equipment you are considering. If so, you may want to include that change in the equipment specification.

**Important** The authors recommend extreme caution in implementing some of the changes under consideration. Be sure to read the *Comments* section in each table describing changes to the standards you are considering.

Continuing with the FACTS example: Of the standards listed in Table 4-4, IEC 61000-4-6 is marked with an asterisk (*) indicating that this standard is being reviewed for change. These changes are discussed in Table 4-14 on page 4-19. After reviewing the changes, you may decide to include them in the equipment specification.

## Step Four: Write the Equipment EMC Specification

Incorporate the existing basic standards and any changes you decide are relevant to the equipment specification you send to the vendor.

## Step Five: Follow the Best EMC Practices in Appendix A to Install and Maintain the Equipment

Appendix A (page A-1) lists the best EMI/EMC practices for substation equipment and operation. Table 4-8 (page 4-9) is a convenient summary to Appendix A to help you identify the specific applicable best practices.

Finishing our FACTS example, Table 4-8 contains a specific entry for FACTS devices and directs you to the following best practices in Appendix A:

- Immunity – Microprocessor-based equipment (best practice #1, p. A-1)
- Immunity – Switchgear (best practice #3, p. A-1)
- Immunity – Installation (best practice #6, p. A-4)
- Immunity – Electrical Fast Transient (EFT) and Oscillatory Waves (OW) (best practice #10, p. A-5)
- Emission –Reduction in measurement distance (best practice #13, p. A-5)
- Emission – Measurement distance and class of equipment (best practice #14, p. A-5)
- Emission – Dimension of equipment (best practice #15, p. A-5)
- Emission – Power Rating (best practice #16, p. A-5)
- Emission – Large electrical machines (best practice #19, p. A-6).

# 4

# TABLES OF STANDARDS

The following tables are designed to help in procuring equipment intended to operate in the harsh EMI substation environment. See Figure 3-1 for a flowchart on using the information in this report.

Table 4-1 displays EMC standards applicable to various types of substation equipment. The test levels applied to ITE and IPM&C equipment do not adequately simulate the EMI levels experienced in a substation and are not sufficient to insure that the equipment will perform properly under substation conditions. Therefore, it is recommended that equipment tested only under those standards undergo testing under more stringent standards. Modification and other “hardening” procedures may be necessary to obtain acceptable testing results (see Note 1 to Table 4-1).

Table 4-2 through Table 4-7 show the specific tests and levels involved in each of the six standards listed in Table 4-1.

Table 4-8 cross-references various aspects of substation equipment and operation to the listing of best EMI/EMC practices in Appendix A.

Figure 4-1 below illustrates the ports tested under IEC standards. Different test levels are required depending on the environment through which the connections to these ports pass, and to which they are connected at the far end.

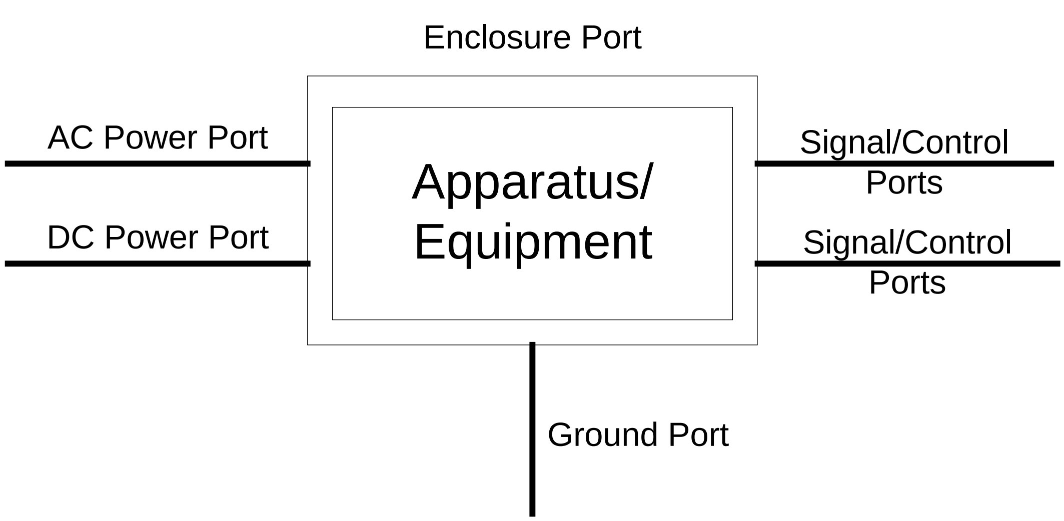


**Figure 4-1**
**IEC Test Ports**

**Table 4-1**
**Utility Equipment Product Standards and Relevant Generic EMC Standards**

| Types of Equipment | IEC 60870-2-1 Tele-control equipment and systems (see Table 4-2) | IEC 60255-26 Equipment comprising measuring or protection relays (see Table 4-3) | IEC 61000-6-5 Other substation equipment (see Table 4-4) | IEC 60439-1 Switchgear &Control gear (see Table 4-5) | IEC 61326 IPM&C Industrial[1] (see Table 4-6) | EN 55024 ITE & Telecoms[1] (see Table 4-7) |
|---|---|---|---|---|---|---|
| | **Severity of Test** Most stringent ------------------------------ Least stringent | | | | | |
| Microwave controls | X | | | | | |
| Relays & associated equipment[2] | | X | | | | |
| Sensors | | | X | | X | |
| Switchgear | | | | X | | |
| Personal Computers (PC) | | | | | | X |
| Microwave communication | | | | | | X |
| Power devices (FACTS) | | | X | | | |
| Power controls | | | X | | X | |
| Metering | | | | | X | |
| Two-way communication, networking, and wireless equipment | | | | | | X |
| Test Equipment | | | | | X | |

[1] IPM&C and ITE immunity levels are only appropriate for typical light industrial & consumer environments. These kinds of products require more stringent testing as “other substation equipment” (IEC 61000-6-5) if used in the substation environment. These last two columns are for information only and should not be used for acquisitions. According to an EPRI report [7]:

“Most equipment is not designed to withstand the range and levels of the testing specified by this report and will not exhibit acceptable results or performance if tested. This is also *true for most commercial grade equipment*. Modifications to equipment shielding, filtering, and grounding may be necessary to achieve performance. Modifications to standard commercial designs required to achieve acceptable testing results must be documented and the installed configuration controlled. Equipment *designs that cannot* be installed with the shielding, grounding, or filtering modifications required to successfully *pass laboratory testing can not be qualified*.”

[2] *Relays and associated equipment* includes the measuring, sensing, control, and communications equipment connected to the relay controller.

**Table 4-2**
**Basic Standards Comprising IEC 60870-2-1: EMC Product Standard for Tele-Control Equipment and Systems (North American Standards are in Underlined Type)**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **EN 55011**<br>**(EN 55011 Class A)** | **IEC 61000-4-6***<br>(see Table 4-14 p.4-19, Table 4-34 p.4-38 and Table 4-42 p.4-45)<br>Level 3 (10V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 61000-4-3***<br>(see Table 4-11 p.4-15 and Table 4-34 p.4-38)<br>Level 4 (30V/m CW)<br>**IEEE C37.90.2/2004**<br>(20V/m with AM) |
| **Power-line**<br>(power cord for EUT) | **IEC 61000-3-2**<br>(Class A harmonic limits)<br>**IEC 61000-3-3**<br>(Mains<16A and 1 kW) | **IEC 61000-4-8***<br>(see Table 4-15 p.4-19 and Table 4-34 p.4-38)<br>Level 4 (100 and 1000 A/m)<br>**IEC 61000-4-10***<br>(see Table 4-17 p.4-20 and Table 4-34 p.4-38)<br>Level 4 (100 A/m)<br>**IEC 61000-4-11***<br>(see Table 4-18 p.4-21 and Table 4-34 p.4-38)<br>(60% and 100% for 0.5 s) |
| **Electrostatic Discharge (ESD)** | | **IEC 61000-4-2***<br>(see Table 4-10 p.4-14, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 4 (8kV & 15kV)<br>**IEEE PC37.90.3/D2.3**<br>Level 4 (8kV & 15kV) |
| **Electrical Fast Transient (EFT)** | | **IEC 61000-4-4***<br>(see Table 4-12 p. 4-16, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Levels 1-4 (0.5kV-4kV)<br>**IEEE C37.90.1**<br>Level 4 (4kV EFT) |
| **Surge** | | **IEC 61000-4-5***<br>(see Table 4-13 p.4-18, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Levels 1-4 (0.5kV-4kV) |
| **Surge Withstand** | | **IEC 61000-4-12***<br>(see Table 4-19 p.4-22 and Table 4-34 p.4-38)<br>Levels 3 & 4 (2kV-2.5kV)<br>**IEEE C37.90.1**<br>(2.5kV oscillatory) |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-3**
**Basic Standards Comprising IEC 60255-26: EMC Product Standard for Measuring Relays and Protection Equipment <u>(North American Standards are in Underlined Type)</u>**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **IEC 60255-25**<br>**<u>(EN55022 Class A)</u>** | **IEC 60255-22-6**<br>Level 3 (10V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 60255-22-3**<br>Level 3 (10V/m with AM)<br>**<u>IEEE C37.90.2/2004</u>**<br><u>(20V/m with AM)</u> |
| **Power-line** (power cord for EUT) | | **IEC 60255-11**<br>(0V for 200ms)<br>**IEC 60255-22-7**<br>Class A: 150 & 300V<br>Class B: 100 & 300V |
| **Electrostatic Discharge (ESD)** | | **IEC 60255-22-2**<br>Level 3 (6kV & 8kV)<br>**<u>IEEE PC37.90.3/D2.3</u>**<br><u>Level 4 (8kV & 15kV)</u> |
| **Electrical Fast Transient (EFT)** | | **IEC 60255-22-4**<br>Class A/Level 3 (2kV/5kHz)<br>Class B/Level 4 (4kV/2.5kHz)<br>**<u>IEEE C37.90.1</u>**<br><u>Level 4 (4kV EFT)</u> |
| **Surge** | | **IEC 60255-22-5**<br>Level 3 (2kV & 1kV) |
| **Surge Withstand** | | **IEC 60255-22-1***<br>(see Table 4-49 p.4-51)<br>(2.5kVcm/1kVdm)<br>**<u>IEEE C37.90.1</u>**<br><u>(2.5kV oscillatory)</u> |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-4**
**Basic Standards Comprising IEC 61000-6-5: Generic EMC Standard for Substation Environments (North American Standards are in Underlined Type)**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **EN 55022**<br>**(EN55022 Class A)** | **IEC 61000-4-6***<br>(see Table 4-14 p.4-19, Table 4-34 p.4-38 and Table 4-42 p.4-45)<br>Level 3 (10V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 61000-4-3***<br>(See Table 4-11 p.4-15 and Table 4-34 p.4-38)<br>Level 3 (10V/m with AM)<br>**IEEE C37.90.2/2004**<br>(20V/m with AM) |
| **Power-line**<br>(power cord for EUT) | **IEC 61000-3-2**<br>(Class A harmonic limits)<br>**IEC 61000-3-3**<br>(Mains <16A & 1kW) | **IEC 61000-4-8***<br>(see Table 4-15 p.4-19 and Table 4-34 p.4-38)<br>Level 2 (CRT monitors)<br>Level 5 (sensors)<br>**IEC 61000-4-11***<br>(see Table 4-18 p.4-21 and Table 4-34 p.4-38)<br>(60% & 100% for 1s)<br>**IEC 61000-4-16***<br>(see Table 4-20 p.4-24 and Table 4-34 p.4-38)<br>Level 4 (30V & 300V)<br>**IEC 61000-4-17***<br>(see Table 4-21 p.4-25 and Table 4-34 p.4-38)<br>Level 3 (10% ripple)<br>**IEC 61000-4-29***<br>(see Table 4-23 p.4-27 and Table 4-34 p.4-38)<br>(30 & 60% dips, 100% interrupt) |
| **Electrostatic Discharge (ESD)** | | **IEC 61000-4-2***<br>(see Table 4-10 p.4-14, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (6kV & 8kV)<br>**IEEE PC37.90.3/D2.3**<br>Level 4 (8kV & 15kV) |
| **Electrical Fast Transient (EFT)** | | **IEC 61000-4-4***<br>(see Table 4-12 p. 4-16, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Levels 3 & 4 (1kV-4kV)<br>**IEEE C37.90.1**<br>Level 4 (4kV EFT) |
| **Surge** | | **IEC 61000-4-5***<br>(see Table 4-13 p.4-18, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Levels 2-4 (1kV-4kV) |
| **Surge Withstand** | | **IEC 61000-4-12***<br>(see Table 4-19 p.4-22 and Table 4-34 p.4-38)<br>Levels 2 & 3 (1kV-2.5kV)<br>**IEEE C37.90.1**<br>(2.5kV oscillatory) |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-5**
**Basic Standards Comprising IEC 60439-1: EMC Product Standard for Low-Voltage Switchgear and Control Gear Assemblies <u>(North American Standards are in Underlined Type)</u>**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **EN 55011** | **IEC 61000-4-6*** <br>(see Table 4-14 p.4-19, Table 4-34 p.4-38 and Table 4-42 p.4-45)<br>Level 3 (10V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 61000-4-3*** <br>(see Table 4-11 p.4-15 and Table 4-34 p.4-38)<br>Level 3 (10V/m with AM)<br><br>**<u>IEEE C37.90.2/2004</u>**<br><u>(20V/m with AM)</u> |
| **Power-line** (power cord for EUT) | | **IEC 61000-4-8*** <br>(see Table 4-15 p.4-19 and Table 4-34 p.4-38)<br>Level 3 (30A/m)<br><br>**IEC 61000-4-11*** <br>(see Table 4-18 p.4-21 and Table 4-34 p.4-38)<br>(30% for half cycle) |
| **Electrostatic Discharge (ESD)** | | **IEC 61000-4-2*** <br>(see Table 4-10 p.4-14, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (4kV & 8kV)<br><br>**<u>IEEE PC37.90.3/D2.3</u>**<br><u>Level 4 (8kV & 15kV)</u> |
| **Electrical Fast Transient (EFT)** | | **IEC 61000-4-4*** <br>(see Table 4-12 p. 4-16, Table 4-34 p.4-38, and Table 4-42 p. 4-45)<br>Level 3 (2kV)<br><br>**<u>IEEE C37.90.1</u>**<br><u>Level 4 (4kV EFT)</u> |
| **Surge** | | **IEC 61000-4-5*** <br>(see Table 4-13 p.4-18, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (2kV&1kV) |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-6**
**Basic Standards Comprising EN 61326: Annex A (Industrial Locations) EMC Product Standard for Measurement, Control and Laboratory Equipment (North American Standards are in Underlined Type)**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **EN 55022**<br>**(EN55022 Class A)**<br>**(EN55011 if product uses ISM frequencies)** | **IEC 61000-4-6***<br>(see Table 4-14 p.4-19, Table 4-34 p.4-38 and Table 4-42 p.4-45)<br>Level 2 (3V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 61000-4-3***<br>(see Table 4-11 p.4-15 and Table 4-34 p.4-38)<br>Level 3 (10V/m with AM)<br>**IEEE C37.90.2/2004**<br>(20V/m with AM) |
| **Power-line**<br>(power cord for EUT) | **IEC 61000-3-2**<br>(Class A harmonic limits)<br>**IEC 61000-3-3**<br>(Mains <16A & 1kW) | **IEC 61000-4-8***<br>(see Table 4-15 p.4-19 and Table 4-34 p.4-38)<br>Level 3 (30A/m)<br>**IEC 61000-4-11***<br>(see Table 4-18 p.4-21 and Table 4-34 p.4-38)<br>(100% for half cycle) |
| **Electrostatic Discharge (ESD)** | | **IEC 61000-4-2***<br>(see Table 4-10 p.4-14, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (4kV & 8kV)<br>**IEEE PC37.90.3/D2.3**<br>Level 4 (8kV & 15kV) |
| **Electrical Fast Transient (EFT)** | | **IEC 61000-4-4***<br>(see Table 4-12 p. 4-16, Table 4-34 p.4-38, and Table 4-42 p. 4-45)<br>Level 3 (2kV)<br>**IEEE C37.90.1**<br>Level 4 (4kV EFT) |
| **Surge** | | **IEC 61000-4-5***<br>(see Table 4-13 p.4-18, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (2kV&1kV) |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-7**
**Basic Standards Comprising EN 55022/EN 55024: EMC Product Standards for Information Technology Equipment (ITE) (North American Standards in Underlined Type)**

| Test | Emissions | Immunity |
|---|---|---|
| **Conducted** | **En 55022**<br>**(EN55022 Class A)** | **IEC 61000-4-6***<br>(see Table 4-14 p.4-19, Table 4-34 p.4-38 and Table 4-42 p.4-45)<br>Level 2 (3V open circuit (emf) with AM[1]) |
| **Radiated** | | **IEC 61000-4-3***<br>(see Table 4-11 p.4-15 and Table 4-34 p.4-38)<br>Level 2 (3V/m with AM)<br><br>**IEEE C37.90.2/2004**<br>(20V/m with AM) |
| **Power-line**<br>(power cord for EUT) | **IEC 61000-3-2**<br>(Class A harmonic limits)<br><br>**IEC 61000-3-3**<br>(Mains <16A & 1kW) | **IEC 61000-4-8***<br>(see Table 4-15 p.4-19 and Table 4-34 p.4-38)<br>Level 1 (1A/m)<br><br>**IEC 61000-4-11***<br>(see Table 4-18 p.4-21 and Table 4-34 p.4-38)<br>(95% & 30%) |
| **Electrostatic Discharge (ESD)** | | **IEC 61000-4-2***<br>(see Table 4-10 p.4-14, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Level 3 (4kV & 8kV)<br><br>**IEEE PC37.90.3/D2.3**<br>Level 4 (8kV & 15kV) |
| **Electrical Fast Transient (EFT)** | | **IEC 61000-4-4***<br>(see Table 4-12 p. 4-16, Table 4-34 p.4-38, and Table 4-42 p. 4-45)<br>Levels 1&2 (0.5kV, 1kV)<br><br>**IEEE C37.90.1**<br>Level 4 (4kV EFT) |
| **Surge** | | **IEC 61000-4-5***<br>(see Table 4-13 p.4-18, Table 4-34 p.4-38, and Table 4-42 p.4-45)<br>Levels 1,2&3 (0.5kV,1kV, 2kV) |

[1] Open-circuit voltage (emf) with amplitude modulation.

* This standard is under review for change, see the tables listed for details.

**Table 4-8**
**Best Substation EMI/EMC Practices**

The reader is referred to the proposed changes to standards discussed in detail in the next section prior to considering the best practices. The following table references Appendix A on page A-1 covering best EMI/EMC practices for a various aspects of substation operation.

| Aspect of Substation Operation | Appendix A Best Practice (Practice No., Page No.) |
|---|---|
| Relays and associated equipment | • Immunity – Switchgear (3, p.A-1)<br>• Emission – Substations (12, p. A-5)<br>• Emission – Reduction in measurement distance (13, p. A-6)<br>• Emission – Measurement distance and class of equipment (14, p. A-5)<br>• Emission – Dimension of equipment (15, p. A-5)<br>• Emission – Power Rating (16, p. A-5)<br>• Emission – Large electrical machines (19, p. A-6) |
| Sensors | • Immunity – Installation (6, p. A-4)<br>• Immunity – Decentralized equipment (7, p. A-4) |
| PCs | • Immunity – Microprocessor-based equipment (1, p. A-1)<br>• Immunity – Installation (6, p. A-4) |
| Microwave communications | • Immunity – Installation (6, p. A-4)<br>• Emission – Substations (12, p. A-5)<br>• Emission – Frequency Range (17, p. A-6) |
| Power devices (FACTS) | • Immunity – Microprocessor-based equipment (1, p. A-1)<br>• Immunity – Switchgear (3, p. A-1)<br>• Immunity – Installation (6, p. A-4)<br>• Immunity – Electrical Fast Transient (EFT) and Oscillatory Waves (OW) (10, p. A-5)<br>• Emission – Reduction in measurement distance (13, p. A-5)<br>• Emission – Measurement distance and class of equipment (14, p. A-5)<br>• Emission – Dimension of equipment (15, p. A-5)<br>• Emission – Power Rating (16, p. A-5)<br>• Emission – Large electrical machines (19, p. A-6) |
| Power controls | • Immunity – Installation (6, p. A-4)<br>• Immunity – Electrical Fast Transient (EFT) and Oscillatory Waves (OW) (10, p. A-5) |

**Table 4-8**
**Best Substation EMI/EMC Practices (Continued)**

| Aspect of Substation Operation | Appendix A Best Practice (Practice No., Page No.) |
|---|---|
| Metering | • Immunity – Installation (6, p. A-4)<br>• Immunity – Electrical Fast Transient (EFT) and Oscillatory Waves (OW) (10, p. A-5) |
| Mobile radios, walkie talkies, and similar telecommunications | • Immunity – Mobile base stations supported by HV structures (8, p. A-4)<br>• Emission – Reduction in measurement distance (13, p. A-5)<br>• Emission – Measurement distance and class of equipment (14, p. A-5)<br>• Emission – Dimension of equipment (15, p. A-5)<br>• Emission – Frequency Range (17, p. A-6)<br>• Emission – Telecommunication systems (22, p. A-6) |
| Test Equipment | • Immunity – Decentralized equipment (7, p. A-4) |
| Wireless networks | • Immunity – Telecommunication equipment linked to substations (2, p. A-1)<br>• Immunity – Installation (6, p. A-4) |
| Broadband Power Line Communication (BPL) | • Emission – Substations (12, p. A-5)<br>• Emission – Frequency Range (17, p. A-6)<br>• Emission – Broadband Power Line (BPL) Communication (18, p. A-6)<br>• Emission – From lines and substations: Corona and Power Line Carrier (20, p. A-6)<br>• Emission – Telecommunication systems (22, p. A-6) |
| *In situ* tests | • Immunity – *In situ* tests (4, p. A-1) |
| Substation environment | • Immunity – Substation environment (5, p. A-4)<br>• Emission – Characteristics of Substation Environments/Immunity – Characteristics of Substation Installations (11, p. A-5)<br>• Emission – Substations (12, p. A-5) |
| Pipelines | • Immunity – Corrosion on pipelines (9, p. A-5) |
| Power lines | • Emission – From lines and substations: Corona and Power Line Carrier (20, p. A-6)<br>• Emission – Power line Harmonics on Telecommunication Circuits (21, p. A-6) |

## Review of Proposed Changes to EMI Standards

Standards evolve as new technologies become available, as issues are discovered, and as experience is gained in the field. The following survey summarizes changes being considered by technical committees and working groups in the United States and Europe that affect substation equipment and environments.

Another important issue driving change is the need to harmonize EMC standards on an international level. In general, harmonization of standards requires several issues to be addressed. A partial list would include: measurement location, frequency band, test level, measurement distance from source and number of measuring points. The following examples illustrate the problem:

1. Generic immunity limits for a severe environment are addressed in the U.S. by ANSI C63.12-1999. A comparison with the European IEC 61000-6-5 standard shows significant differences:
   - The ANSI standard specifies a 100 A/m H-field pulse while the IEC standard calls for a 100 A/m continuous and 1000 A/m for 1-second disturbance.
   - The ANSI standard specifies a 200 V/m E-field while the IEC standard specifies 10 V/m.
   - The IEC standard treats ports differently depending on the type of exposure whereas the ANSI standard does not.
2. CISPR 11 requires as many measuring points as is reasonably practical in the azimuth and at least four measurements in the orthogonal direction; ANSI Std 430-1986 requires that measurements be repeated at intervals not exceeding 10 m (32.81 feet) around the entire perimeter of the substation.
3. CISPR 18 covers the frequency range 100 kHz to 1 GHz whereas ANSI C63.12 covers 0.9k Hz to 10 GHz. Scanning of the complete frequency range, especially at power electronic installations, is time consuming. Due to cost considerations, the number of measurement points should be limited to those necessary.

Some new standards are demanding significantly more stringent emission requirements than existing standards. New standards may be more influenced by standards for typical industrial environments than for HV substation environments. The range of industrial equipment with radio frequency (RF) emissions is perceived to be larger than that for HV substations thereby driving the limits for typical industrial environments to be more stringent. CIGRE WG C4.2.02 monitors and influences the situation at the standard setting level.

**Table 4-9**
**List of Standards, Guidelines, and Topics Covered**

| Standard/Topic/Guideline | Table(s) |
|---|---|
| BPL communications | Table 4-41 (p. 4-44) |
| CIGRE EMC Guide 124 | Table 4-27 (p. 4-30), Table 4-28 (p. 4-32), Table 4-34 (p. 4-38) |
| CIGRE Guide 20 | Table 4-43 (p. 4-47) |
| CIGRE Guide 95 | Table 4-33 (p. 4-37) |
| CISPR | Table 4-36 (p. 4-40) |
| CISPR 11 | Table 4-37 (p. 4-41), Table 4-41 (p. 4-44) |
| CISPR 16 | Table 4-38 (p. 4-42), Table 4-41 (p. 4-44) |
| CISPR 18 | Table 4-40 (p. 4-43) |
| EN 55011 | Table 4-42 (p. 4-45) |
| IEC 60255-22-1 | Table 4-49 (p. 4-51) |
| IEC 60255-27 | Table 4-47 (p.4-49) |
| IEC 60255-26 | Table 4-48 (p. 4-50) |
| IEC 60694 | Table 4-26 (p. 4-29) |
| IEC 61000-4-2 | Table 4-10 (p. 4-14), Table 4-34 (p. 4-38), Table 4-42 (p. 4-45) |
| IEC 61000-4-3 | Table 4-11 (p. 4-15), Table 4-34 (p. 4-38) |
| IEC 61000-4-4 | Table 4-12 (p. 4-16), Table 4-34 (p. 4-38), Table 4-42 (p. 4-45) |
| IEC 61000-4-5 | Table 4-13 (p.4-18), Table 4-34 (p. 4-38), Table 4-42 (p. 4-45) |
| IEC 61000-4-6 | Table 4-14 (p.4-19), Table 4-34 (p.4-38), Table 4-42 (p.4-45) |
| IEC 61000-4-8 | Table 4-15 (p.4-19), Table 4-34 (p.4-38) |
| IEC 61000-4-9 | Table 4-16 (p. 4-20), Table 4-34 (p.4-38) |
| IEC 61000-4-10 | Table 4-17 (p.4-20), Table 4-34 (p. 4-38) |
| IEC 61000-4-11 | Table 4-18 (p. 4-21), Table 4-34 (p. 4-38) |
| IEC 61000-4-12 | Table 4-19 (p. 4-22), Table 4-34 (p. 4-38) |
| IEC 51000-4-16 | Table 4-20 (p. 4-24), Table 4-34 (p. 4-38) |

**Table 4-9**
**List of Standards, Guidelines, and Topics Covered (Continued)**

| Standard/Topic/Guideline | Table(s) |
|---|---|
| IEC 61000-4-17 | Table 4-21 (p. 4-25), Table 4-34 (p. 4-38) |
| IEC 61000-4-18 | Table 4-22 (p. 4-26), Table 4-34 (p. 4-38) |
| IEC 61000-4-29 | Table 4-23 (p. 4-27), Table 4-34 (p. 4-38) |
| IEC 61000-5-2 | Table 4-29 (p.4-33) |
| IEC 61000-6-2 | Table 4-27 (p. 4-30), Table 4-32 (p. 4-36), Table 4-35 (p. 4-40) |
| IEC 61000-6-5 | Table 4-27 (p. 4-30), Table 4-30 (p. 4-34), Table 4-34 (p. 4-38), Table 4-35 (p. 4-40) |
| IEC 61326 Ed 1.0 | Table 4-46 (p. 4-49) |
| IEC 61800-3 | Table 4-39 (p.4-42) |
| IEEE 367-1996 | Table 4-25 (p. 4-28) |
| IEEE 487-1998 | Table 4-25 (p. 4-28) |
| Immunity – microprocessor-based equipment | Table 4-24 (p.4-27) |
| ITU Directives I-IX | Table 4-25 (p. 4-28) |
| ITU, Directives of the | Table 4-44 (p. 4-48) |
| ITU-T Recommendation K. 57 | Table 4-31 (p. 4-35) |
| Telecommunications systems | Table 4-45 (p.4-48) |

**Table 4-10**
**Proposed Changes to IEC 61000-4-2: Electrostatic Discharge**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 3<br>IPM&C: level 3<br>ITE: level 3 |
| Standard likely to be affected by proposed change | IEC 61000-4-2 Electrostatic Discharge |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/MT 12: Electrostatic discharges immunity tests |
| Application of Standard to the substation environment | This test simulates the effect of transient currents flowing adjacent to, or in the casing of, susceptible equipment. For the substation environment, the test gives an effective indication of the likely susceptibility of the receptor equipment to potential interference in the substation environment. |
| Proposed or actual change | The main changes to be included are:<br>• Modify the ESD waveform by removing the second hump (apparently this can be achieved without altering the specification of the existing gun)<br>• Modify the test set-up to agree with other standards (i.e. test on a 10 cm high stand above the horizontal conducting plane)<br>• Waveform calibration to require characterization of the test set up (requires knowledge of the real bandwidth of the test system). |
| Rationale for proposed change | Bring standard into agreement with other standards.<br>Under some circumstances, problems with reproducibility have been encountered with the present standard. |
| Status of change | Changes and clarifications of the standard are being reviewed by a maintenance team (MT 12) because of a failure to reach agreement in the normal revision process. A revised version of the standard is not expected until 2009.<br>Second committee draft (CD) with comments to be issued for circulation within the Technical committee (2001). |
| Comments | |
| Organization | IEC |

**Table 4-11**
**Proposed Changes to IEC 61000-4-3: Radiated Radio Frequency Electromagnetic Fields**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 3<br>IPM&C: level 3<br>ITE: level 2 |
| Standard likely to be affected by proposed change | IEC 61000-4-3 Radiated Radio Frequency Electromagnetic Field - The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 10: Immunity to radiated electromagnetic fields and to conducted disturbances induced by these fields |
| Application of Standard to the substation environment | This test evaluates the performance of the equipment when subjected to electromagnetic fields, primarily the transient fields generated by electricity supply plant but also the permanent fields generated by portable and base station radio transceivers.<br>The effectiveness of the test in simulating the transient interference from primary plant is limited because it applies the interference as a series of discrete frequencies. However this is the only standard radiated interference test which is available from the majority of test houses. |
| Proposed or actual change | The range of the test is to be extended to 6 GHz to cover new interference sources such as Radio Frequency Identification. |
| Rationale for proposed change | Expand standard to cover new interference sources. |
| Status of change | Publication date for amendment/revision: 2005. |
| Comments | |
| Organization | IEC |

**Table 4-12**
**Proposed Changes to IEC 61000-4-4: Electrical Fast Transient/Burst**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 3 & 4<br>IPM&C: level 3<br>ITE: level 1 & 2 |
| Standard likely to be affected by proposed change | IEC 61000-4-4 Electrical Fast Transient/Burst - The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 11: Immunity to conducted disturbances<br>(except conducted disturbances induced by radiated fields) |
| Application of Standard to the substation environment | The test (normally abbreviated to EFT) is intended to simulate the effects of transient disturbances originating in SF6 plant during switching operations and also other switching transients (interruption of inductive loads, relay bounce, etc). |
| Proposed or actual change | 1. Waveform verification into 50Ω and 1,000Ω is now required.<br>a. Close tolerance required on these test impedances i.e. 50Ω ±2%, 1,000Ω ±2% << 6pf. It is understood that commercial verification tools are now available to meet this requirement.<br>b. The tolerance on the peak voltage measurement using the 1 kΩ load has been relaxed from +10%/-15% to ±20%.<br>2. The waveform is to be verified at the output of the coupling-decoupling network (CDN) rather than the output of the generator. It is understood that adaptors are now commercially available to accurately measure the EFT waveform at the output of the CDN.<br>3. The waveform is to be verified at the coupler output at 50Ω, common mode.<br>4. A change in the optional frequencies, the 2.5 kHz requirement, has been dropped and a new frequency of 100 kHz has been added. The previous 5 kHz requirement has been retained. The number of spikes per burst remains constant at 75 so that the energy transferred from the test generator to the EUT remains constant regardless of the spike frequency.<br>5. All testing is to be carried out in common mode only. For mains coupling it is now required that all lines are coupled simultaneously to ground to give true common mode coupling. The generator/CDN must also be verified in this mode and must meet all waveform requirements. When multi-line common mode coupling is selected the added load of the CDN may reduce the burst amplitude. Care must be taken to ensure that compensation is applied to account for this attenuation. Commercial systems will normally advise the correction factors to be applied.<br>6. Changes have been made in the test set-ups. |

**Table 4-12**
**Proposed Changes to IEC 61000-4-4: Electrical Fast Transient/Burst (Continued)**

| | |
|---|---|
| Rationale for proposed change | The main driver behind changes 1 to 3 is to ensure that the waveform that is actually applied to the EUT is correct. Previously the waveform could change dramatically when the test equipment was connected to the EUT so that the test was not representative of the actual severity of the substation environment. The main differences between the signal produced by the EFT generator and the actual wave shape of the disturbance are as follows: (1) With the actual relay switching phenomenon, the amplitude of the disturbance increases with the number of disturbances, (2) the rise time is extended whereas the fall time is shortened; (3) the repetition rate is not constant and the burst is followed by a low frequency modulation. However, this does not appear to be significant as long as the test signal maintains the same severity level as the phenomenon it is meant to simulate.<br>The main parameters defining this severity level, apart from amplitude, are rise time and repetition rate. This is the main reason for change number 4; there is general consensus that the repetition rate is too low but the rise time is satisfactory. The 2.5 kHz requirement has been dropped as it was only introduced into the original issue of the standard as a compromise because the original electromechanical test equipment was incapable of generating 4 kV pulses at 5 kHz. Normal interference phenomena are better represented by the 5 kHz test. |
| Status of change | |
| Comments | It is likely that the 100 kHz option would better represent the phenomena to be encountered in a substation and consideration should be given to testing receptor equipment at this frequency. However, IEC 61000-6-5 does not, as yet, include these new test frequencies (either 5 or 100 kHz).<br>Although it has been noted that some equipment passing the EFT test failed when tested with a generator producing much steeper spikes (about 1 ns rise time), measurements have not demonstrated the existence of disturbances with such fast rise times (aside from ESDs). It is therefore not appropriate to propose any modification of the test requirements on this basis.<br>See also the comments in Table 4-19. |
| Organization | IEC |

**Table 4-13**
**Proposed Changes to IEC 61000-4-5: Surge**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 2-4<br>IPM&C: level 3<br>ITE: level 1, 2, & 3 |
| Standard likely to be affected by proposed change | IEC 61000-4-5 Surge – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 11: Immunity to conducted disturbances (except conducted disturbances induced by radiated fields) |
| Application of Standard to the substation environment | This test simulates overvoltages caused by switching and lightning transients. |
| Proposed or actual change | 1. Define many different CDNs for different coupling requirements.<br>2. Allow smaller decoupling inductors for high current CDNs to reduce the voltage drop.<br>3. Verify the waveform at the CDN output. This is to ensure that the waveform actually applied to the EUT is correct.<br>4. Define test requirements less ambiguously.<br>5. When testing non-distributed auxiliary power supply systems, the impedance of the test generator has been changed to 42Ω from 12Ω. |
| Rationale for proposed change | 1. The original standard did not adequately address the requirements of different test scenarios; for example, using telecom lines.<br>2. Reduce the voltage drop for high current CDNs.<br>3. Ensure that the waveform actually applied to the EUT is correct.<br>4. The previous wording caused misunderstanding of requirements; for example, the number of surges to be applied.<br>5. This change was justified since the line impedance of these power supplies is higher than normal distributed supplies and the 12Ω requirement caused over-testing of the power supply. |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-14**
**Proposed Changes to IEC 61000-4-6: Conducted Disturbances Induced by RF Fields**

| | |
|---|---|
| Type of equipment and applicable test level | IPM&C: level 2<br>ITE: level 2 |
| Standard likely to be affected by proposed change | IEC 61000-4-6 Conducted Disturbances Induced by RF Fields – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 10: Immunity to radiated electromagnetic fields and to conducted disturbances induced by these fields |
| Application of Standard to the substation environment | This test determines the immunity of the EUT to electromagnetic fields which act on the cables connected to the EUT. |
| Proposed or actual change | None. |
| Rationale for proposed change | |
| Status of change | |
| Comments | Since the test applies the interference as a series of discrete frequencies, its effectiveness in simulating the transient interference from primary plant is limited. |
| Organization | IEC |

**Table 4-15**
**Proposed Changes to IEC 61000-4-8: Power Frequency Magnetic Field Immunity**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 2 (CRT monitors) 5 (sensors)<br>IPM&C: level 3<br>ITE: level 1 & 2 |
| Standard likely to be affected by proposed change | IEC 61000-4-8 Power Frequency Magnetic Field Immunity – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 10: Immunity to radiated electromagnetic fields and to conducted disturbances induced by these fields |
| Application of Standard to the substation environment | This test would normally only be applied to equipment which utilizes an electron beam (cathode ray tube monitors, electron microscopes, etc.) or to certain measuring instruments. |
| Proposed or actual change | None |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-16**
**Proposed Changes to IEC 61000-4-9: Pulsed Magnetic Field**

| | |
|---|---|
| Type of equipment: | Control equipment in the switchyard |
| Standard likely to be affected by proposed change | IEC 61000-4-9 Pulsed Magnetic Field – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 10: Immunity to radiated electromagnetic fields and to conducted disturbances induced by these fields |
| Application of Standard to the substation environment | This test simulates the magnetic field generated by<br>• lightning strokes<br>• initial fault transients<br>• switching of HV busbars and lines by circuit breakers. |
| Proposed or actual change | None |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-17**
**Proposed Changes to IEC 61000-4-10: Damped Oscillatory Magnetic Field**

| | |
|---|---|
| Type of equipment: | Control equipment in the switchyard |
| Standard likely to be affected by proposed change | IEC 61000-4-10 Damped Oscillatory Magnetic Field – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 10: Immunity to radiated electromagnetic fields and to conducted disturbances induced by these fields |
| Application of Standard to the substation environment | Damped Oscillatory Magnetic Fields are generated by the switching of HV busbars by disconnectors. The test as specified in IEC 61000-4-10 requires oscillatory waves of 0.1 and 1.0 MHz. There is some evidence [8] that 10 kHz and 10 MHz versions of this waveform are also often present in the spectrum of the interference emanating from primary plant (10 kHz in the case of AIS circuit breakers; 10 MHz from GIS disconnectors and circuit breakers and some AIS disconnectors [10]). Since the interference field is confined to the vicinity of the current breaking device, the test would normally only be required for receptor equipment located close to this type of primary plant. |
| Proposed or actual change | The above notwithstanding, none are currently planned. |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-18**
**Proposed Changes to IEC 61000-4-11: Voltage Dips, Interruptions and Slow Variations**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: 60%-100% for 1 s.<br>IPM&C: 100% for half cycle<br>ITE: 95% and 30% |
| Standard likely to be affected by proposed change | IEC 61000-4-11 Voltage Dips, Interruptions and Slow Variations – The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77A/WG 2: Voltage fluctuations and other low-frequency disturbances |
| Application of Standard to the substation environment | Receptor equipment in a substation, as any other environment, may be susceptible to variations in its supply voltage. Equipment containing electro-mechanical devices such as disc drives may be particularly susceptible to this type of interference and may suffer damage if not appropriately protected. |
| Proposed or actual change | 1. Add an 80% dip.<br>2. Add phase to phase testing for three phase testing.<br>3. Change to the step profile to give a rapid step down followed by a gentle ramp up to the original level. |
| Rationale for proposed change | These changes have been introduced to represent the real-world situation more effectively; in other words, they are based on a more statistical/risk assessment approach. |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-19**
**Proposed Changes to IEC 61000-4-12 Damped Oscillatory Wave**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 2 & 3 |
| Standard likely to be affected by proposed change | IEC 61000-4-12 Damped Oscillatory Wave - The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 11: Immunity to conducted disturbances<br>(except conducted disturbances induced by radiated fields) |
| Application of Standard to the substation environment | This test is intended to simulate the effects of switching with restrike of the arc (for example, during disconnector operations). |
| Proposed or actual change | 1. The definition of the damping circuit is corrected.<br>2. A new standard (61000-4-18) will be introduced to address the requirement of GIS primary plant in the electricity substation environment (see above) and also HEMP.<br>3. The present standard (61000-4-12) will confine itself to the Ring Wave Test.<br>4. 61000-4-18 will specify the Damped Oscillatory Wave Test at 3MHz, 10MHz and 30MHz. |
| Rationale for proposed change | For HV substations, it has been shown [8, 9, 10] that the maximum pseudo frequencies encountered could extend from tens of kHz in air-insulated substations (AIS) to several tens of MHz in gas-insulated substations (GIS). Accordingly it was decided to introduce a new standard, 61000-4-18 for substation and HEMP requirements and to retain the current standard for the non-repeating Ring Wave Test only. |
| Status of change | |
| Comments | Based on the experience of several utilities and test laboratories, the following statements can be made:<br>1. Most equipment passing the EFT test (see Table 4-12) also passes the oscillatory wave (OW) test. However, the contrary is seldom true. Thus, the EFT test is considered more severe due to the higher frequency content and a different coupling method.<br>2. The EMI environments of HV substations can be considered to have increased in severity, particularly in its frequency spectrum with regard to cabling and mitigation. The reason for this perceived increase in severity is the reduction in separation distances (for example, reduction of the overall sizes of substations, the use of gas insulated substations (GIS), and the installation of electronic equipment nearer to switching devices). |

**Table 4-19**
**Proposed Changes to IEC 61000-4-12 Damped Oscillatory Wave (Continued)**

| | |
|---|---|
| | 3. The EFT test can be considered, to some extent, a time domain test whereas the OW test (particularly the damped oscillatory test) is more of a frequency domain test. Therefore, even if both tests had the same frequency spectrum, they would remain complementary as their mechanisms of interference with the EUT differ.<br><br>A time domain test is less reproducible compared to a frequency domain test because the wave shape of the signal, and its rise time is dependant on the load/source impedance ratio and the transfer function of coupling device (damping effect). This is less significant in the case of the frequency domain test.<br><br>The differences in energy content of both test signals are also a factor to consider in justifying their complementary existence.<br><br>4. The coupling methods of the two tests are also quite different. The EFT coupling is basically common mode capacitively coupled and well suited for testing installed equipment. The OW test specifies application of transients, and is capacitively coupled in any possible combination of the conductors for all input and output ports.<br><br>It is the opinion of the WG that reducing the differences in coupling methods would simplify the number of tests, methods, and devices. The standards could be based on a fixed set of generators, a fixed set of coupling devices (not specifically linked to the generators) and a fixed set of coupling methods (common mode and differential mode). It has been shown that the EFT test could be applied using a bulk inductive coupling device (as in the case of IEC 61000-4-6). This is sometimes a far more practical solution than the use of the traditional capacitive clamp and is also of great interest in terms of *in situ* tests performed on large equipment or installations.<br><br>However, EFT test equipment with clamp injection is currently not available and commonly available bulk current injection probes cannot be used as their connectors cannot withstand 4kV and their primary windings would arc to the case if the connectors do not break down first. EFT is usually coupled onto I/O lines using the specified capacitive coupling clamp which is widely available.<br><br>**The authors strongly caution against opening any HV test equipment and inserting anything into the pulse-forming network. This can lead to a lethal injury.** |
| Organization | IEC |

**Table 4-20**
**Proposed Changes to IEC 61000-4-16 (See Also IEC 60255-22-7) Immunity to Conducted, Common Mode Disturbances in the Frequency Range 0 Hz to 150 kHz**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 4 |
| Standard likely to be affected by proposed change | IEC 61000-4-16 (see also IEC 60255-22-7) Immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz-The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77A/WG 2: Voltage fluctuations and other low-frequency disturbances |
| Application of Standard to the substation environment | This test is required to simulate the effect of an earth fault in the substation and to verify that the system is immune to any picked up mains frequency interference during non-fault conditions. In order to best represent the effects of an earth fault it is recommended that the test method used is that specified in IEC 60255-22-7 (Electrical disturbance tests for measuring relays and protection equipment - Power frequency immunity tests). This standard is based on EN 61000-4-16 but includes a differential mode test and uses different coupling capacitors and test voltages. |
| Proposed or actual change | None notified |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-21**
**Proposed Changes to IEC 61000-4-17 Ripple on D.C. Input Power Port**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: level 3 |
| Standard likely to be affected by proposed change | IEC 61000-4-17 Ripple on DC input power port - The EUT should operate without any problems throughout and after the test. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77A/WG 2: Voltage fluctuations and other low-frequency disturbances |
| Application of Standard to the substation environment | This test simulates ripple on the DC input power ports due to AC rectification and battery charging. |
| Proposed or actual change | None notified |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-22**
**Proposed Introduction of IEC 61000-4-18**

| | |
|---|---|
| Type of equipment: | Generic EMC standard for substation environments: level 2 & 3 |
| Standard likely to be affected by proposed change | IEC 61000-4-18 (see also 61000-4-12, Table 4-19) |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77B/WG 11: Immunity to conducted disturbances (except conducted disturbances induced by radiated fields) |
| Application of Standard to the substation environment | This test is intended to simulate the effects of switching with restrike of the arc (for example, during a disconnector operation). There is evidence [8, 9, 10] that 10 kHz and 10 MHz versions of this interference are often present in the interference emanating from primary plant (10 kHz in the case of AIS circuit breakers; 10 MHz from GIS disconnectors and circuit breakers and some AIS disconnectors). |
| Proposed or actual change | 1. The present standard (61000-4-12) will confine itself to only the Ring Wave Test.<br>2. 61000-4-18 will specify the Damped Oscillatory Wave Test at 3 MHz, 10 MHz and 30 MHz.<br>3. 61000-4-18 is likely to specify the waveshape to have a 5 ns rise time as does the EFT waveform. This would facilitate the design of common test generator platforms. |
| Rationale for proposed change | For HV substations, it has been shown [8, 9, 10] that the maximum pseudo frequencies encountered could extend from tens of kHz in air-insulated substations (AIS) to several tens of MHz in gas-insulated substations (GIS).<br>This requirement, together with that for testing for high altitude electromagnetic pulse (HEMP) immunity, justified the introduction of this new test standard. |
| Status of change | |
| Comments | One important consideration of this approach is that such a set of frequencies (0, 1, 3, 10, and 30 MHz) leaves several bands unattended in the spectrum. It is likely that some resonant frequencies present in the electronic system could be excited by actual oscillatory phenomena but missed by the selected frequencies of the test impulse. One solution could be the use of a sweep test generator, however the general opinion of many users is that the number of different tests should be limited to as few tests as possible.<br>Specific tests for each possible source of disturbance are not required. A minimum set of tests should represent all possible disturbances present in a given environment. Product Committees and Generic Standard Committees can then select the subset of standards and the severity levels according to their needs.<br>These specifications should include (bearing in mind the constraints of the available test equipment) not only voltage level but also wave shape, repetition rate, frequency band and source impedance or the coupling device if these are parameters to be defined in a specific basic standard. |
| Organization | IEC |

**Table 4-23**
**Proposed Changes to IEC 61000-4-29 Voltage Dips, Short Interruptions and Voltage Variations on DC Input Power Port**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments: 30% and 60% dips, 100% interruptions |
| Standard likely to be affected by proposed change | IEC 61000-4-29 Voltage Dips, Short Interruptions and Voltage Variations on DC Input Power Port |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | SC 77A/WG 2: Voltage fluctuations and other low-frequency disturbances |
| Application of Standard to the substation environment | This test simulates disturbances on the DC input power ports caused by variations in loads and in on/off switching of loads. |
| Proposed or actual change | None notified |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-24**
**Proposed Changes to Standards Involving Immunity of Microprocessor-Based Equipment**

| | |
|---|---|
| Type of equipment: | Immunity – microprocessor-based equipment |
| Standard likely to be affected by proposed change | The specific standards are reflected in the sections to come. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01<br>WG C4.2.02 |
| Application of Standard to the substation environment | The influx of more sensitive equipment in substations is realized and standards are adapted to cover the emission in the substation environment and the immunity of the new equipment. |
| Proposed or actual change | Addresses immunity of equipment in secondary environments. This is a general statement covered in more detail in other sections of this report (see Table 4-27 p. 4-30, Table 4-28 p. 4-32, and Table 4-34 p. 4-38). |
| Rationale for proposed change | As discussed in the introductory sections, technology turnover in the secondary environment occurs more rapidly than that in the primary environment. These newer technologies are more sensitive to EMI as opposed to the technologies they are replacing. |
| Status of change | This point has already received some attention and will remain relevant until sufficiently addressed. |
| Comments | See also Table 4-35, p 4-40. |
| Organization | CIGRE |

**Table 4-25**
**Proposed Changes to IEEE 367-1996, IEEE 487-1998 and ITU Directives (Vol I to IX)**

| | |
|---|---|
| Equipment/Environment Affected | Immunity - telecommunication equipment linked to substations. |
| Standard likely to be affected by proposed change | IEEE 367-1996, IEEE 487-1998 and ITU Directives (Vol I to IX) |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | Within the ITU, these questions would be considered by the ITU-T Study Group 5 (Protection against electromagnetic environment effects).<br>In CIGRE, this work will fall with WG C4.2.02. |
| Application of Standard to the substation environment | It is recommended that the work be done to better understand the stress imposed on the telecommunication circuits entering the substation because this affects the method or the type of equipment required for their protection.<br>Hydro-Quebec operates its own telecommunication system and has been using an alternative method of protecting its circuits entering substations.<br>Calculations can be made to verify that the thermal capabilities of the telecommunication system are not exceeded during a fault. |
| Proposed or actual change | The standard(s) to be reviewed are a result of newly published data from the past 10 years that suggest the zone of influence concept is not applicable in practice because HV substations are not isolated. Earth wires of HV lines, neutrals of MV and LV cables or overhead lines can transfer the earth potential rise (EPR) outside the substation. This aspect is poorly covered in existing standards. |
| Rationale for proposed change | Practical experience has shown that during fault conditions, there has been negligible disturbances to telephone central offices which are bonded to multiple-grounded neutral distribution systems connected to a substation with high soil resistivity. Further, the equipment required in achieving isolation in the zone of influence and its subsequent maintenance are costly.<br>Measurements done by Hydro-Quebec's IREQ have shown that, during a fault, the voltage between tip-and-ring and ground for circuits serving the substation or LV installations in the proximity of the substation are similar. However, only those circuits serving the substation are isolated. |
| Status of change | A more detailed discussion at a working group level is proposed. |
| Comments | This proposal is relevant to fixed-line telecommunication systems. Wireless telecommunication systems are covered in Table 4-31, p 4-35. |
| Organization | ITU<br>IEEE<br>CIGRE |

**Table 4-26**
**Proposed Changes to IEC 60694**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity - Switchgear |
| Standard likely to be affected by proposed change | IEC 60694 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | Immunity of switchgear as covered in this standard has direct application for substation design and EMC requirements. |
| Proposed or actual change | Clarify the test conditions and how they integrate with EMC design relating to the earth mat, lightning protection, cable ducts and cable shielding. |
| Rationale for proposed change | IEC 60694 indirectly regulates electromagnetic emission from substations. Sections 2.1.1g, 5.18, 6.9 and 6.9.2 define immunity requirements for secondary systems of switchgear and control gear. Section 2.1.1.g defines a maximum induced disturbance of 1.6 kV common mode for normal EMC severity class and 0.8kV common mode for reduced EMC severity class. This is an indirect requirement for substation EMC design relating to the earth mat, lightning protection, cable ducts and cable shielding.<br><br>Section 6.9.2.2 specifies that "the immunity tests" involved in this standard "are intended to cover a majority of service conditions". Such conditions may be extreme situations where induced disturbances are more severe than those covered by the tests in the standard. |
| Status of change | This topic is listed as an agenda item for future WG discussions. |
| Comments | |
| Organization | CIGRE |

**Table 4-27**
**Proposed Changes to CIGRE EMC Guide 124, IEC 61000-6-2, IEC 6100-6-5**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity – *in situ* tests |
| Standard likely to be affected by proposed change | 1) CIGRE EMC Guide 124<br>2) IEC 61000-6-2<br>3) IEC 61000-6-5 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01<br>WG C4.2.02 |
| Application of Standard to the substation environment | The methods considered may not develop to an international standard. It could be presented as a guide used by the utility engineer and the contractor.<br>It would be important for manufacturers and users of equipment to work together to achieve success with *in situ* testing.<br>The test technique could take on the form of current injection (or of voltages with simultaneous monitoring of the related current) on the cabling through the use of bulk injection or electromagnetic clamp devices. The purpose of these new methods is not to replace the existing basic standards which are effective in laboratory testing (in other words, on the equipment alone), but to offer complementary test methods with sufficient repeatability and traceability to be used *in situ* in a cost-effective way. |
| Proposed or actual change | Develop a new and suitable test technique that can fulfill the need of *in situ* tests in substation environments. |
| Rationale for proposed change | 1. There are no standardized immunity test procedures for large fixed installations.<br>2. Equipment is in some cases custom designed and forms an extension of an existing installation through an extended cable network.<br>3. Some equipment cannot be tested unless connected to larger equipment that cannot easily be transported to a laboratory test area.<br>4. A piece of equipment may be tested at a certain level and may be immune to this level, but to determine at which level it becomes susceptible requires higher levels of interference, more time and therefore more costly. Thus, immunity testing is easier and less costly to do than susceptibility testing.<br>5. Coupling/decoupling networks are not always available as three-phase, high power systems. |

**Table 4-27**
**Proposed Changes to CIGRE EMC Guide 124, IEC 61000-6-2, IEC 6100-6-5 (Continued)**

| | |
|---|---|
| | 6. Intelligent sensors, decentralized electronic systems and field buses are becoming more widespread.<br><br>7. *In situ* testing will provide confidence in system performance during EMI assessments and commissioning tests.<br><br>8. The outcome of EMC tests, and hence overall immunity of a system to disturbances, is largely dependent on cabling and earthing practices. These are difficult to simulate under laboratory conditions.<br><br>9. Equipment that originates from various countries need to be tested as an integrated system.<br><br>10. *In situ* testing is considered important in preserving EMC.<br><br>11. There is a lack of test methods below 30 MHz for conducted interference exists.<br><br>12. There is a general trend to find a substitute test method and to replace radiated tests by conducted test or, at least, to show some equivalence between them.<br><br>13. The general consensus is that common mode currents play a major part in the coupling mechanism of interferences in HV substations. This makes current injection techniques an attractive candidate to apply in *in situ* tests.<br><br>(The potential risk of disturbance to other electronic equipment is important to consider in *in situ* testing). |
| Status of change | Discussion by the working group is proposed. |
| Comments | *In situ* testing could be hazardous with a strong risk of disturbance to other electronic equipment. It is the opinion of the authors that *in situ* immunity testing of any substation equipment not be attempted when actual loads are connected. *In situ* immunity testing should only be carried out during commissioning or diagnostic testing of substation equipment to ensure the safety of customers, utility equipment and personnel. See Appendix A, Best Practice No. 4. |
| Organization | CIGRE could get involved in developing a suitable test method. The WG focus is likely to be limited to the development of systematic technical *in situ* test methods. The objective is not to develop a standard but rather a useful tool for the utility. |

**Table 4-28**
**Proposed Changes to CIGRE EMC Guide 124, Immunity in the Substation Environment**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity - Substation environment |
| Standard likely to be affected by proposed change | CIGRE, EMC Guide Publication 124 [11] |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01 |
| Application of Standard to the substation environment | The work of this group (and the former WG 36-04) mainly focused on the characterization of the environment, the immunity of equipment and on the mitigation techniques. Its main activities in the recent years has been the edition of the CIGRE EMC Guide 124 (1997) [11], the contribution to the IEC standard (Technical Specification) IEC 61000-6-5, a position paper for IEC in the field of Transient Immunity Tests (IEC TC77B (Firenze)) [12], and the publication of the paper on EMI characterization of HVAC substations – updated data and influence on immunity assessment [10].<br><br>All these documents can be considered as concluding the work of the Task Force. These can be considered the state of the art in the field of EMC in power installations. The main activity of the Task Force now focuses on maintenance work. In particular, liaison is maintained with IEC for the revision of several basic, generic (mainly IEC 61000-6-5) and product standards. |
| Proposed or actual change | Review and update the existing CIGRE EMC Guide, Publication 124 [11]. |
| Rationale for proposed change | The Guide was published as a CIGRE Technical document on EMC in power plant and substations in 1997. Since the publication, significant and new information have been published, demanding the update and review of the Guide.<br><br>Updated information on various aspects include but are not limited to: (1) transient phenomena, (2) practical applications, (3) interference barriers, (4) design criteria, (5) test methods and requirements, (6) perspectives on cables from various countries and (7) Smart Yards.<br><br>A list of applicable standards was prepared by Joint Task Force (JTF) 23/13/33/34/36. |

**Table 4-28**
**Proposed Changes to CIGRE EMC Guide 124, Immunity in the Substation Environment (Continued)**

| | |
|---|---|
| Status of change | Initial meetings were held to discuss the outline and possible contributions.<br><br>A time frame of three years was set with a target of 2006/2007.<br><br>After completion of the work, other EMC topics are likely to be addressed by the TF which could focus on general immunity problems. The future scope of TF C4.2.01 could become "EMC immunity problems in power and industrial installations".<br><br>Possible areas and topics to be covered in a revised version of the Guide have been identified. These need to be agreed upon by the working group for incorporation into a preparation schedule that will be developed into a revised EMC Guide. |
| Comments | The CIGRE EMC Guide is a useful reference, valuable to the utility EMC engineer. |
| Organization | CIGRE |

**Table 4-29**
**Proposed Changes to IEC 61000-5-2**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity – Installation |
| Standard likely to be affected by proposed change | IEC 61000-5-2 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01<br><br>TC 77 |
| Application of Standard to the substation environment | This is an example of a standard that developed from the CIGRE EMC Guide 124 [11]. |
| Proposed or actual change | No changes are proposed. |
| Rationale for proposed change | N/A |
| Status of change | The standard has been published and is available from IEC. |
| Comments | This is a valuable reference for the utility EMC engineer. |
| Organization | CIGRE<br><br>IEC |

**Table 4-30**
**Proposed Changes to IEC 61000-6-5**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity for power station and substation environments |
| Standard likely to be affected by proposed change | IEC 61000-6-5 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02<br>TC77B<br>TC17A |
| Application of Standard to the substation environment | The following proposals are made for future revision of the document:<br>1. Revise the applicability of IEC 61000-4-4, IEC 61000-4-5 and IEC 61000-4-12 in relation to the location of the equipment and the port involved.<br>2. Include a field test (IEC 61000-4-9 and/or IEC 61000-4-10) for equipment located in the switchyard or in its close vicinity.<br>Liaison with IEC 17A/MT 34 in terms of maintenance of IEC 60694 will be initiated to analyze the environment for HV equipment incorporating decentralized electronics. |
| Proposed or actual change | IEC 61000-6-5 does not address decentralized equipment. It is proposed that the topic of decentralized equipment be incorporated in this standard.<br>See also Table 4-32, p. 4-36. |
| Rationale for proposed change | New activities have started in the field of EMC assessment of large systems and of systems involving distributed electronics (decentralized electronics or electronics embedded in HV equipment). These systems have not yet been treated adequately in terms of standardization, either because the EMC environment is not properly defined or because compliance of individual pieces of equipment does not necessarily imply compliance of the whole system. |
| Status of change | The changes are proposed for discussion and for incorporation in a future edition. The first edition of the standard has been published (2001) and is available from IEC. |
| Comments | See comment in Table 4-12 regarding the preferred EFT test frequencies.<br>This is a valuable reference to the utility EMC engineer. |
| Organization | CIGRE<br>IEC |

**Table 4-31**
**Proposed Changes to ITU-T Recommendation K.57**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity – Mobile base stations supported by HV structures |
| Standard likely to be affected by proposed change | ITU-T Recommendation K.57. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | CIGRE Joint Working Group C4.2.02 and ITU-T SG 5 |
| Application of Standard to the substation environment | During the last few years the major drive has been the preparation of a new ITU-T recommendation on Protection measures for radio base stations sited on power line towers. This recommendation has been completed and has been published as ITU-T Recommendation K 57 [13]. The WG prepared a summary of this recommendation published as a condensed version in CIGRE Technical Brochure 266 with an Executive summary in Elektra of Feb 2005 [14]. |
| Proposed or actual change | This is a new publication with no further changes envisaged. |
| Rationale for proposed change | A long term ongoing activity within WG C4.2.02 is related to the revision and updating of the ITU-T Directive, a document jointly signed by ITU-T, CIGRE and UIC. The work is normally initiated by ITU-T. |
| Status of change | No further changes are planned. |
| Comments | |
| \Organization | CIGRE<br>ITU |

**Table 4-32**
**Proposed Changes to IEC 61000-6-2**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity – Decentralized equipment |
| Standard likely to be affected by proposed change | IEC 61000-6-2 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01<br><br>TC 77 |
| Application of Standard to the substation environment | Decentralised electronics, automation and their electromagnetic compatibility finds direct application in the substation environment, including substation planning and design. |
| Proposed or actual change | 1. Decentralized equipment should be covered in this standard (see also Table 4-30, p. 4-34).<br><br>2. The RF test frequency should be extended up to 2 GHz. |
| Rationale for proposed change | New activities have started in the field of EMC assessment of large systems and of systems involving distributed electronics (decentralized electronics or electronics embedded in HV equipment). These systems have not yet been treated adequately in terms of standardization, either because the EMC environment is not properly defined or because compliance of individual pieces of equipment does not necessarily imply compliance of the whole system. |
| Status of change | The CIGRE WG may consider starting work on decentralized equipment in order to initiate and establish a link with IEC.<br><br>IEC may not immediately revise the standard when requested due a waiting period of about five years following the publication of a standard. |
| Comments | |
| Organization | CIGRE<br><br>IEC |

**Table 4-33**
**Proposed Changes to CIGRE Guide 95 on Metallic Pipelines**

| | |
|---|---|
| Equipment/Environment Affected: | Immunity – Corrosion on pipelines |
| Standard likely to be affected by proposed change | CIGRE Guide 95 on Metallic Pipelines [15]. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | The applicability of this Guide falls perhaps more with long transmission lines than substations per se. The Guide should still be considered where pipelines run in close proximity to substations. |
| Proposed or actual change | It is proposed that a Technical Brochure be developed to complement the existing CIGRE Publication 95 on pipelines. |
| Rationale for proposed change | The WG is preparing a new guide on AC corrosion on pipelines caused by interference from HV AC power lines. New information has become available that can complement the existing CIGRE Technical Brochure No. 95 (1995). |
| Status of change | The work will be completed towards the end of 2005. |
| Comments | |
| Organization | CIGRE<br><br>The work is performed in cooperation with the Committee on the Study of Pipe Corrosion and Protection (CEOCOR). |

**Table 4-34**
**Proposed Changes to Standards Addressing Characteristics of Substation Environments and Characteristics of Substation Installations**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Characteristics of Substation Environments<br><br>Immunity – Characteristics of Substation Installations |
| Standard likely to be affected by proposed change | 1. CIGRE Guide 124 [11].<br><br>2. IEC 61000-4 series<br><br>3. Specifically related to immunity assessment: differences between Product Standards, such as, IEC 61000-6-2, UNIPEDE Norm Spec [16], and IEC 61000-6-5 are analyzed in terms of comparison between minimum requirements and utility requirements.<br><br>4. The WG presented the position paper (36-108) to the IEC that resulted in a revision of the IEC standards [10].<br><br>5. IEC 61000-6-5 has absorbed the table of the known UNIPEDE document.<br><br>6. Some of the values in IEC 61000-6-5 are not similar to those in the UNIPEDE document and should be confirmed [16]. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | C4.2.01<br><br>TC77B |
| Application of Standard to the substation environment | With the disturbances in HV substation environments reliably characterized and related environmental levels defined, discussions about possible improvements in terms of EMC testing, are initiated.<br><br>These discussions include new proposals for testing electronics in the control room taking into account, for example, common mode currents that can flow in the armoring of control cables of HV substations during disconnector operations.<br><br>Based on the experience in field measurements, tests covering fast transients, surge and oscillatory waves are analyzed and discussed.<br><br>An important point of the analysis indicates the need for standardization bodies to address and set up *in situ* testing procedures required in assessing the immunity of large installations against electromagnetic disturbances. |
| Proposed or actual change | 1. Proposal: Update CIGRE Guide 124 [11] with information from CIGRE Paper 36-108, 2002 [10].<br><br>2. The IEC 61000-4 series do not specify levels of electromagnetic interference but rather immunity test levels. The data in paper 36-108 could assist in confirming that these levels are adequate. |

**Table 4-34**
**Proposed Changes to Standards Addressing Characteristics of Substation Environments and Characteristics of Substation Installations (Continued)**

| | |
|---|---|
| Rationale for proposed change | Gas insulated substations (GIS) are becoming more attractive in view of the limited access to large property space and the demand for reduced size air insulated substations (AIS). The reduction in size tends to result in electromagnetic disturbances at higher frequencies than that encountered with traditional air-insulated substations.<br>Reliable characterization of the transient electromagnetic environment (in terms of levels, waveforms and spectra) both in the HV yard and inside the control room, is important from an EMC perspective.<br>These characteristics of the electromagnetic environment can then be compared with compatibility and adequacy of equipment immunity levels.<br>The paper reflects on :<br>• Updated data from a measurement campaign spanning ten years in HV substations conducted by authors.<br>• A critical comparison with recent publications.<br>• Managing the data to rationally upgrade or extend EMC tests and standards. |
| Status of change | The material covered by paper 36-108 [10] has been identified for incorporation in the revised Guide and will follow the incorporation process referred to in Table 4-28, p 4-32. |
| Comments | The reader is referred to the data presented in paper 36-108 [10] for updated information on substation EM environments. |
| Organization | CIGRE<br>IEC<br>UNIPEDE |

**Table 4-35**
**New Standard Equivalent to IEC 61000-6-2 and IEC 61000-6-5**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Substations |
| Standard likely to be affected by proposed change | New standard equivalent to IEC 61000-6-2 and IEC 61000-6-5. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.01<br><br>TC 77 |
| Application of Standard to the substation environment | Possible consideration by the WG in terms of performing initial work towards developing an emission standard equivalent to IEC 61000-6-2 and IEC 61000-6-5. |
| Proposed or actual change | It is proposed that an emission standard specific to substation environments be published. |
| Rationale for proposed change | There is no commonly existing standard referring to emissions from substations. This results in a confusing situation when comparing standards. |
| Status of change | The document IEC 61000-6-4: Generic Standards – Emission Standard for Industrial Environments, is currently in circulation as a committee draft for voting (CDV) with a closing date of 15 Jul 2005. |
| Comments | The documents discussed and required are highly relevant and of direct application to EMC in substations. |
| Organization | CIGRE<br>IEC |

**Table 4-36**
**Proposed Changes Emissions Related to a Reduction in Measurement Distance**

| | |
|---|---|
| Equipment/Environment Affected: | Emission -Reduction in measurement distance |
| Standard likely to be affected by proposed change | CISPR |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | Measurement distance is of direct relevance to electromagnetic interference measurements in close proximity to substations. |
| Proposed or actual change | No change is proposed. It is, however, important for limits not to become stricter without technical justification. |
| Rationale for proposed change | There appears to be an emerging trend in the application of limits: levels previously defined at a specified distance from a substation, are now applied at distances closer to the substation. This implies a reduction in emission levels in order to maintain the same reading at a closer distance. |
| Status of change | This aspect is likely to be considered at the working group level. |
| Comments | |
| Organization | CIGRE |

**Table 4-37**
**Proposed Changes to CISPR 11**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Measurement distance and class of equipment |
| Standard likely to be affected by proposed change | CISPR 11 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | Measurement distance is of direct relevance to electromagnetic interference measurements in close proximity to substations. |
| Proposed or actual change | The following are to be addressed:<br>• Frequency band<br>• Measurement distance<br>• The use of E-field antennas close to HV equipment and influence on measurement results.<br>• Contextualize the standard in terms of measurements in substations. |
| Rationale for proposed change | CISPR 11 reflects on limits, above 30 MHz, for Group 1, Class A equipment at 30 m (98.4 ft) from the wall of the building considered. In view of large dimensions of the installation and frequencies involved (including switching frequencies) from MVA power electronic equipment, the following questions arise:<br>• Is the frequency band adequately covered?<br>• Is the measuring distance of 30 m appropriate for substation measurements?<br>• CISPR 11 also calls for E-field levels at 30m employing an antenna in a HV environment at the distance mentioned. Are the measurements affected by the environment? |
| Status of change | The proposed questions are listed for discussion by the working group. |
| Comments | |
| Organization | CIGRE<br>IEC/CISPR |

**Table 4-38**
**Proposed Changes to CISPR 16**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Dimension of equipment |
| Standard likely to be affected by proposed change | CISPR 16 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | Equipment dimensions are of direct relevance to electromagnetic interference measurements in close proximity to substations. |
| Proposed or actual change | No specific change is proposed for the standard. The applicability of this standard in terms of its application to substation measurements needs to be reviewed. |
| Rationale for proposed change | CISPR 16 covers industrial, scientific, and medical (ISM) equipment operating at high frequencies. The physical dimensions of ISM equipment are in most cases smaller than that of a substation. In addition, the geographical density of the ISM equipment is likely to be higher than that of substations. |
| Status of change | The applicability of this standard in substation environments to be discussed by the working group. |
| Comments | |
| Organization | CIGRE |

**Table 4-39**
**Proposed Changes to IEC 61800-3**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Power Rating |
| Standard likely to be affected by proposed change | IEC 61800-3 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02<br>TC 77B |
| Application of Standard to the substation environment | The Working Group will address the proposed expansion directly relevant to the increase in power rating of fast switching technologies applied in substations. |
| Proposed or actual change | Expand the standard to cover high power rated devices typically found in substations. |
| Rationale for proposed change | In IEC 61800-3, the emission part refers to CISPR 11 and covers EMC requirements for power electronic equipment with a lower rating than that typically found in substations (FACTS and HVDC converter stations). |
| Status of change | The topic has been suggested for discussion by the working group. |
| Comments | |
| Organization | CIGRE<br>IEC |

**Table 4-40**
**Proposed Changes to CISPR 18**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Power Rating<br>Emission – Frequency Range |
| Standard likely to be affected by proposed change | CISPR 18 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | CISPR 18 covers radio interference from power lines and high voltage equipment, including interference from insulators, fittings, thyristor valve firing and substation equipment. |
| Proposed or actual change | Expand the standard to cover for high power rated devices typically found in substations.<br>Consider extension of the frequency range from 9 kHz to 18 GHz. |
| Rationale for proposed change | In IEC 61800-3, the emission part refers to CISPR 11 and covers EMC requirements for power electronic equipment with a lower rating than that typically found in substations (FACTS and HVDC converter stations).<br>In CISPR 18-2, Amendment 2 covers the frequency characteristics of HVDC. The frequency spectrum from power electronic equipment using semi-conductor components with high current extinction capacity, such as GTOs and IGBTs, may be higher than that indicated. |
| Status of change | The topic has been proposed for future discussion at working group level. |
| Comments | |
| Organization | CIGRE |

**Table 4-41**
**Proposed Changes to Standards Involving Broadband Power Line Communications**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Broadband Power Line (BPL) Communication |
| Standard likely to be affected by proposed change | Several standards may form the normative references to standard on BPL. These include:<br>• FCC Report & Order 04-245 [17]<br>• CISPR 16 [18]<br>• CISPR 22 [19]<br>• CISPR 11 [20]<br>• ETSI EN 300 330-1 V1.3.1 (2001) [21]<br>• ANSI C63.4-2001 [22]<br>• FCC Title 47, Titles 0 to 19 [23]<br>• ETSI TR 102 324 V1.1.1 (2004-5) [24]<br>• ETSI EN 300 386 V1.3.2 (2003 -05) [25]<br>• CENELEC CLC/prTS 50217 [26]<br>• CENELEC EN 55022:1998 [27]<br>• CENELEC EN 55024:1998 [28]<br>• IEEE 1613-2003 [29] |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02<br>CISPR/I/WG3<br>CENELEC SC205A<br>IEEE |
| Application of Standard to the substation environment | Substations are likely to be the environment to house the coupling equipment for the communication system. The standard(s) therefore has direct application in this context. |
| Proposed or actual change | There is at present no single product standard addressing BPL. It is proposed that a standard be developed. |
| Rationale for proposed change | Although BPL is perhaps more applicable in the context of distribution than transmission, it is important to note the following:<br>• The emission levels measured from BPL could be higher than some standards allow 15 m (49.2 ft) outside an HV substation.<br>• A separation distance rather than an emission level should be considered to balance the cost in emission reduction against the low number of people that may be affected, the area of impact, and emissions levels from household equipment. |

**Table 4-41**
**Proposed Changes to Standards Involving Broadband Power Line Communications (Continued)**

| | |
|---|---|
| | • Technical details such as height of measurement, location of antenna, and antenna orientation are required. |
| Status of change | This topic is presently being addressed by organizations including CIGRE and IEEE. |
| Comments | A main focus area is the measurement protocol. |
| Organization | CIGRE<br>CISPR<br>CENELEC<br>IEEE |

**Table 4-42**
**Proposed Changes Affecting Generic Standards for Substations Environments, IPM&C, and ITE Equipment**

| | |
|---|---|
| Type of equipment and applicable test level | Generic EMC standard for substation environments:<br>IEC 61000-4-2: level 3<br>IEC 61000-4-4: level 3 & 4<br>IEC 61000-4-5: levels 2-4<br>IEC 61000-4-6: level 3<br>IPM&C:<br>IEC 61000-4-2: level 3<br>IEC 61000-4-4: level 3<br>IEC 61000-4-5: level 3<br>IEC 61000-4-6: level 2<br>ITE:<br>IEC 61000-4-2: level 3<br>IEC 61000-4-4: level 1 & 2<br>IEC 61000-4-5: level 1, 2, & 3<br>IEC 61000-4-6: level 2 |

**Table 4-42**
**Proposed Changes Affecting Generic Standards for Substations Environments, IPM&C, and ITE Equipment (Continued)**

| | |
|---|---|
| Standard likely to be affected by proposed change | New test methods and alternatives to be developed could be based on the following standards (list not exhaustive):<br>EN 55011<br>IEC 61000-4-2<br>IEC 61000-4-4<br>IEC 61000-4-5<br>IEC 61000-4-6 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TC210 (CENELEC)<br>TC77 (IEC)<br>TF C4.2.01 and WG C4.2.02 (CIGRE) |
| Application of Standard to the substation environment | New test methods and design guidelines to be developed are addressed. |
| Proposed or actual change | The development and validation of alternative on-site EMC test methods for specifically testing large and medium electrical machines. |
| Rationale for proposed change | 1. Manufacturers of large electrical machines have the responsibility to demonstrate compliance according to the requirements of the EMC Directive.<br>2. Demonstrating such compliance is particularly challenging and difficult in terms of technical and economic feasibility. |
| Status of change | Proposals have been made for new standards to be developed. |
| Comments | |
| Organization | TEMCA2 (European research project funded by the 5th Framework Program of the European Commission)<br>CENELEC<br>IEC<br>Work will be performed in close relation to European standardization bodies.<br>Possible collaboration with CIGRE. |

**Table 4-43**
**Proposed Changes to CIGRE Guide 20**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – From lines and substations: Corona and Power Line Carrier |
| Standard likely to be affected by proposed change | CIGRE Guide 20 [30] |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TF C4.2.01 |
| Application of Standard to the substation environment | CIGRE Guide 20 could be updated to include corona aspects associated with base stations operating at 1.8 GHz and 2.1 GHz (UMTS).<br><br>In terms of the WG activities, no further action is required. The topic will remain on the agenda for further study in the context of field mitigation. In terms of power line communication (PLC), no specific action to be undertaken. |
| Proposed or actual change | There is no immediate need for technical discussions at CIGRE. Some points of interest are mentioned. |
| Rationale for proposed change | Power lines are considered as fixed installations in the EU Directive. Compliance of such fixed installations are not tested during or following commissioning. Any complaints resulting from disturbances are responded to in a reactive rather than pro-active manner. Further, the limits of CISPR 18 are not mandatory and the definition of equipment does not include lines and substations.<br><br>There are no CISPR emission limits for existing lines; emission limits for new lines are under discussion.<br><br>Corona loss appears to be of interest to some utilities. Although a minor problem, it could become more important in cross-border transmission of power between countries. |
| Status of change | No specific action has been identified. |
| Comments | |
| Organization | CIGRE |

**Table 4-44**
**Proposed Changes Directives of the ITU**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Power line Harmonics on Telecommunication Circuits |
| Standard likely to be affected by proposed change | Directives of the ITU. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | This will be addressed by the WG in the future. |
| Proposed or actual change | Addresses the effect of harmonics in AC HV power lines on telecommunication circuits. |
| Rationale for proposed change | Experience has shown harmonics in AC HV power lines could affect telecommunication circuits. |
| Status of change | No specific action has been identified. |
| Comments | |
| Organization | These CIGRE activities will be included in general activities covered through co-operation with ITU-T. |

**Table 4-45**
**Draft Standards Influencing Telecommunication Systems**

| | |
|---|---|
| Equipment/Environment Affected: | Emission – Telecommunication systems |
| Standard likely to be affected by proposed change | CENELEC has introduced two draft standards related to the influence on telecommunication systems (prEN50351 [31] and prEN50352 [32]). Input from CIGRE was significant with coordination from the side of ITU-T. |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | WG C4.2.02 |
| Application of Standard to the substation environment | Standards cover interference from power supply and traction lines with telecommunication systems. |
| Proposed or actual change | The WG will technically assist in the updating of standards.<br>Long term relationship will be maintained with IEC and CENELEC. |
| Rationale for proposed change | An important activity of CIGRE relates to maintaining a long-term relationship with IEC and CENELEC in order to update standards concerned with the influence of power networks on other networks. |
| Status of change | Documents are in a voting phase and have not yet been published. |
| Comments | |
| Organization | CIGRE<br>ITU-T<br>CENELEC |

**Table 4-46**
**Proposed Changes to IEC 61326 Ed 1.0**

| | |
|---|---|
| Equipment/Environment Affected: | Measurement, control and laboratory equipment |
| Standard likely to be affected by proposed change | IEC 61326 Ed. 1.0 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | Subcommittee 65A Working Group 4 on EMC |
| Application of Standard to the substation environment | |
| Proposed or actual change | This work will divide the existing Standard into two parts: Part 1 will cover General Requirements and Part 2 will cover Product Specific Requirements for the EMC testing of industrial process, measurement and control products. |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-47**
**Proposed Changes to IEC 60255-27**

| | |
|---|---|
| Equipment/Environment Affected: | Product safety requirements for measuring relays and protection equipment |
| Standard likely to be affected by proposed change | IEC 60255-27 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TC95 |
| Application of Standard to the substation environment | Product safety will have a serious impact on relay design requirements and on the acceptability of existing designs in markets guided by IEC 60255-27. Several Working Group members reviewed the draft prior to the vote deadline and found no unacceptable features. Some low-cost relaying equipment couldn't pass these product safety tests required of most electronic devices. An insulation failure could result in an operator being shocked when touching the controls of such a product during a fault condition. |
| Proposed or actual change | This standard addresses mechanical, construction, insulation, and materials requirements |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-48**
**Proposed Changes to IEC 60255-26**

| | |
|---|---|
| Equipment/Environment Affected: | Electromagnetic compatibility requirements for measuring relays and protection equipment |
| Standard likely to be affected by proposed change | IEC 60255-26 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TC95 |
| Application of Standard to the substation environment | This standard provides a concise, tabulated overview of all the recently issued TC 95 standards for electrical environment testing of relays. |
| Proposed or actual change | |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

**Table 4-49**
**Proposed Changes to IEC 60255-22-1**

| | |
|---|---|
| Equipment/Environment Affected: | Electrical disturbance tests for measuring relays and protection equipment |
| Standard likely to be affected by proposed change | IEC 60255-22-1 |
| Technical Committee (TC), Working Group (WG), or Task Force (TF) | TC95 |
| Application of Standard to the substation environment | |
| Proposed or actual change | Burst immunity tests at 1 MHz have been accepted with no significant technical changes and moves on to Final Draft International Standard (FDIS) balloting. The test has a single set of levels – 2.5 kV common mode and 1 kV differential mode for process I/O and 1 kV common mode only for communications ports. Communications ports for temporary connections, or short connections (< 3 m), are exempted. The CDV (Committee Draft for Voting) version of this Standard has incorporated changes in the damping factor of the waveform that are really just clarifications. The test equipment did not have to be re-designed and this new version reflects these subtle changes in the underlying Basic Standard IEC 61000-4-12 (discussed separately under TC77B/WG11) as applied to the testing of relay controllers. |
| Rationale for proposed change | |
| Status of change | |
| Comments | |
| Organization | IEC |

# A
# BEST PRACTICES FOR EMI/EMC TESTING

This listing of best EMI/EMC practices is keyed to various aspects of substation operation in Table 4-8 on page 4-9.

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| 1 | Immunity – Microprocessor-based equipment, PCs | Best practice for installation is covered in CIGRE EMC Guide, 124, 1997 [11].<br><br>See Table 4-24 (p.4-27), Table 4-27 (p.4-30), Table 4-28 (p.4-32), Table 4-34 (p.4-38) |
| 2 | Immunity - Telecommunication equipment linked to substations. | IEEE 367-1996, IEEE 487-1998 and ITU Directives (Vol I to IX) still present best practice. However, it must be ensured that the isolation equipment offers the level of protection required.<br><br>See Table 4-25 (p. 4-28), Table 4-44 (p. 4-48). |
| 3 | Immunity – Switchgear | Apply IEC 60694 taking cognizance of the proposed change.<br><br>See Table 4-26 (p. 4-29). |
| 4 | Immunity – *In situ* tests | In order to perform an effective assessment without the aid of an *in situ* test, the assessment needs to be representative of the interference phenomena. The assessment should further be done according to classical immunity tests. These are covered in IEC 61000-2-3 and IEC 61000-4-1.<br><br>The most relevant and existing test methods include:<br>• IEC 61000-4-2 (see Table 4-10 p.4-14, Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-3 (see Table 4-11 p.4-15, Table 4-34 p.4-38)<br>• IEC 61000-4-4 (see Table 4-12 p.4-16, Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-5 (see Table 4-13 p.4-18 Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-6 (seeTable 4-14 p.4-19 Table 4-34 p.4-38, Table 4-42 p.4-45) |

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| | | • IEC 61000-4-8 (see Table 4-15 p.4-19, Table 4-34 p.4-38)<br>• IEC 61000-4-9 (see Table 4-16 p.4-20, Table 4-34 p.4-38)<br>• IEC 61000-4-10 (see Table 4-17 p.4-20, Table 4-34 p.4-38)<br>• IEC 61000-4-11 (see Table 4-18 p.4-21, Table 4-34 p.4-38)<br>• IEC 61000-4-12 (see Table 4-19 p.4-22, Table 4-34 p.4-38)<br><br>**Electrostatic discharge**<br><br>As stated in the basic standard (IEC 61000-4-2) the specifications for the test can be performed on equipment in the final installation and the test be considered as a “post installation test”. Section 7.2 of the standard described the test set up that can be applied. The 61000-4-2 test should be applied in each environment where there exists some risk of ESD (presented by people or by furniture).<br><br>Experience has shown that even where the risk of ESD was very low it was useful applying the test to check the immunity of the equipment (installation) against other types of fast transients currents. The mechanism of interference resulting from ESD does not only represent a high voltage stress (sometimes destructive to electronic components) but also include a current stress of several amperes presented the discharge and flowing in the shielding, bonding or earthing conductors of the equipment. This current, in turn, is very often able to induce transient voltages acting as the source of severe interference.<br><br>As such, and recognizing the weakness of the non-repetitiveness of the pulses, the ESD test can be considered as supplementary to the fast transient test.<br><br>**Radiated radio frequency**<br><br>The test procedure covered in IEC 61000-4-3 is very difficult to apply *in situ*, as it is impossible to shield the equipment under test from the 10 V/m field (with modulation) at 3 m distance that implies some 100 W RF power which is not allowed to radiated in free space. Further, large size EUT need to be illuminated partially, implying long and costly procedures. On the other hand, as the field strength homogeneity is highly influenced by the environment it is important to be able to monitor the field level and to apply some feedback to the source in order to control the applied level. |

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| | | **Electrical Fast Transient**<br><br>The test covered in IEC 61000-4-4 can be applied *in situ* as proposed in Section 7.3 of the standard.<br><br>It is possible to replace the capacitive coupling clamp with an aluminum tape, foil or with “zipper” tubing enclosing the cables under test. Bulk current injection clamps are also useful.<br><br>Inductive current injection has the advantage of ensuring measurement repeatability as opposed to capacitive injection.<br><br>The clamp device can also be used to inject transient currents into the cable under test.<br><br>Thus, with only a few additional pieces of test equipment, this test can be very useful in *in situ* immunity testing.<br><br>**Surge**<br><br>The surge immunity test is difficult to apply *in situ* because it normally involves the use of coupling/decoupling networks not easily inserted without modifying the cabling. However, it can be used to test shielded cables or to apply a potential difference between EUT.<br><br>The test generator is used in this case as a current source and not as a voltage source.<br><br>It should be noted that IEC 61000-4-5 is the only immunity test where both the open circuit and the short circuit waveform of the generator is defined.<br><br>The surge test is also useful in testing I/O circuits equipped with (external) Surge Protective Devices (SPD’s) or fitted with EMC barriers such as insulation transformers or optical separations.<br><br>**Conducted disturbances, induced by radio frequency fields**<br><br>IEC 61000-4-6 presents a good substitute. The clamped injection technique is probably the most suitable. An *in situ* test is typically directed at testing a complete and cabled installation and not a single piece of equipment. In addition, to test the equipment in its normal environment, and it is not necessary to introduce decoupling networks on the cabling. Direct injection on screened cables via a 100 $\Omega$ resistor can also be applied.<br><br>In terms of extending the frequency range to higher frequencies (230 MHz), it should be noted that the procedure only makes sense when the injection is made very close to the EUT. |

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| | | **Oscillatory waves immunity tests**<br><br>The damped oscillatory wave test can be considered a useful complement to the electrical fast transient (EFT) test in simulating switching transients in power installations.<br><br>The coupling to the cabling is normally capacitive and needs the use of a coupling/decoupling network (CDN) for both differential mode and common mode).<br><br>This is not easy to apply *in situ*. The high value of the coupling capacitor (0.5 μF) makes it practically impossible to use aluminum foil, zipper tubing or any other kind of distributed capacitance for transient injection. However, similarly to the electrical fast transient (EFT) test, inductive coupling could be used in injecting common mode currents, representing a damped oscillatory waveform, into the cabling. |
| 5 | Immunity - Substation environment | The EMC Guide 124 [11] is viewed as an important source of information that not only contributes but also impacts the development of IEC standards through the strong linkage that exists between CIGRE and IEC. In particular, Part 2 of the IEC 61000 series describes the environment.<br><br>It should be noted that the intention is not to provide single solutions to EMI problems (a recipe book approach will do more harm than good). But the Guide provides options to achieve EMC. The role of the EMC engineer should be recognized as imperative in solving EMC problems.<br><br>See Table 4-27 (p. 4-30), Table 4-28 (p. 4-32), Table 4-34 (p. 4-38). |
| 6 | Immunity – Installation | IEC 61000-5-2 is considered as covering the best installation and mitigation practices.<br><br>See Table 4-29 (p.4-33) |
| 7 | Immunity – Decentralized equipment | IEC 61000-6-5 should be used as a guideline for all product committees and in the future replaces the UNIPEDE Norm Spec specification.<br><br>IEC 61000-6-2 should be used taking cognizance of the proposed changes.<br><br>See Table 4-27 (p. 4-30), Table 4-32 (p. 4-36), and Table 4-35 (p. 4-40). |
| 8 | Immunity – Mobile base stations supported by HV structures | ITU-T Recommendation K 57 [13] is considered best practice. This Standard contains special bonding and installation practices for power supplies to mobile base stations with antennas supported by HV structures. Because these sites are supplied by MV distribution, it may be necessary to consider differences between grounding of MV systems in Europe and the U.S.: solidly grounded in |

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| | | the U.S. (higher fault current); grounded through impedance in Europe (lower fault current).<br><br>See Table 4-31 (p.4-35). |
| 9 | Immunity – Corrosion on pipelines | Best practice is covered in CIGRE Technical Publication No 95: "Guide on the Influence of HVAC Power Systems on Metallic Pipelines", 1995 [15]. |
| 10 | Immunity – Electrical Fast Transient (EFT) and Oscillatory Waves (OW) | Although the origins and scope of these two tests are quite different, they should be considered as two complementary tests able to reproduce most of the possible sources of HF transients and not specifically the result of switching LV inductive loads (EFT) or HV equipment (OW).<br><br>The EFT waveform represents more the shape of the source of disturbance before coupling to the victim, whereas the OW is representative of the result of the coupling, taking into account some resonance effects in the cabling. |
| 11 | Emission – Characteristics of Substation Environments<br><br>Immunity – Characteristics of Substation Installations | The following covers best practice:<br><br>1. IEC 61000-6-2 (see Table 4-27 p.4-30, Table 4-32 p.4-36, Table 4-35 p.4-40)<br><br>2. IEC 61000-6-5 with consideration of the paper published (see Table 4-27 p.4-30, Table 4-30 p.4-34, Table 4-34 p.4-38, Table 4-35 p.4-40).<br><br>Good agreement was found between immunity standards and basic standards in terms of EMI characterization in substation environments. |
| 12 | Emission – Substations | Refer to CIGRE Paper 36-108, 2002 [10]. |
| 13 | Emission –Reduction in measurement distance | CISPR 11 is considered best practice.<br><br>See Table 4-37 (p. 4-41), Table 4-41 (p. 4-44). |
| 14 | Emission – Measurement distance and class of equipment | CISPR 11 is considered best practice taking into account the proposal under discussion.<br><br>See Table 4-37 (p. 4-41), Table 4-41 (p. 4-44). |
| 15 | Emission – Dimension of equipment | Best practice covered by CISPR 11. The applicability of CISPR 16 in the context of substation environments is questioned.<br><br>See Table 4-37 (p. 4-41), Table 4-38 (p. 4-42), Table 4-41 (p. 4-44) |
| 16 | Emission – Power Rating | Best practice is covered by IEC 61800 taking cognizance of the aspect to be considered.<br><br>See Table 4-39 (p.4-42) |

| Ref No. | Technology/Aspect Affected | Best Practice Considered |
|---|---|---|
| 17 | Emission – Frequency Range | EPRI Technical Report TR-102323 Rev. 2 [33] presents the state of the art and guides on how to do measurements and how to apply the limits. |
| 18 | Emission – Broadband Power Line (BPL) Communication | FCC Report & Order 04-245 [17]<br><br>CISPR 16-1 [18]<br><br>CISPR 22 [20]<br><br>FCC Part 15 is typically used as basis in the measurement [23].<br><br>EPRI publication 1011663, "BPL FCC Emissions Compliance Guidelines" [34], provides good background to the topic. It is also recommended that developments be followed on the IEEE Website [35]. |
| 19 | Emission – Large electrical machines<br><br>Ref: TEMCA2 and<br><br>www.temca2.org | The existing emissions standards :<br>• EN 55011 (See Table 4-42 p.4-45)<br>• IEC 61000-4-2 (See Table 4-10 p.4-14, Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-4 (See Table 4-12 p.4-16, Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-5 (See Table 4-13 p.4-18 Table 4-34 p.4-38, Table 4-42 p.4-45)<br>• IEC 61000-4-6 (See Table 4-14 p.4-19 Table 4-34 p.4-38, Table 4-42 p.4-45)<br><br>are considered best practice but have limited use in on site testing of large machines. |
| 20 | Emission – From lines and substations: Corona and Power Line Carrier | CIGRE Guide 20 [30] covers best practice in terms of corona aspects. When performing line compaction, for example, it is necessary to address corona. The EPRI red book has recently been updated with input from Eskom and covers some additional information on corona [36]. |
| 21 | Emission – Power line Harmonics on Telecommunication Circuits | Best practices are covered through the Directives of the ITU [37]. |
| 22 | Emission – Telecommunication systems | Best practices to be covered in prEN50351 [31] and prEN50352 [32]. |

# B
# ABBREVIATIONS

AIS – Air Insulated Substation

AM – Amplitude Modulation

ANSI – American National Standards Institute

BPL – Broadband Power Line communication

CENELEC – European Committee for Electrotechnical Standardization

CDN – Coupling-Decoupling Network

CDV – Committee Draft for Voting

CEOCOR – Committee on the Study of Pipe Corrosion and Protection

CIGRE – International Council on Large Electric Systems

CISPR – International Special Committee on Radio Interference

EFT – Electrical Fast Transient

EM - Electromagnetic

EMC – Electromagnetic Compatibility

EMI – Electromagnetic Interference

EPR – Earth Potential Rise

ESD – Electrostatic Discharge

ETSI – European Telecommunications Standards Institute

EUT – Equipment Under Test

FACTS – Flexible AC Transmission System

FCC – Federal Communications Commission (US)

FDIS – Final Draft International Standard

FT – See Electrical Fast Transient (EFT)

GIS – Gas Insulated Substation

GTO –Gate Turn-Off thyristor

HEMP – High Altitude Electromagnetic Pulse

HV – High Voltage

HVDC – High Voltage Direct Current

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

IGBT – Insulated Gate Bipolar Transistor

IPM&C – Industrial Process, Measurement, and Control equipment

ISM – Industrial, Scientific, and Medical equipment

ITE – Information Technology Equipment

ITU – International Telecommunication Union

ITU-T – ITU Telecommunication Standardization Sector

JTF – Joint Task Force

LV – Low Voltage

MV – Medium Voltage

OW – Oscillatory Wave test

PLC – Power Line Carrier

RF – Radio Frequency

SF6 – Sulfur Hexafluoride

SPD – Surge Protective Device

STATCOM – Static Compensator

TC – Technical Committee

TF – Task Force

UIC – International Union of Railways

UMTS – Universal Mobile Telecommunication System

UNIPEDE – International Union of Producers and Distributors of Electrical Energy

WG – Working Group

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