EMC - BEYOND 1996

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ABSTRACT

This paper introduces and defines the concepts of Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC), together with their relationship to Quality of Supply (QOS). Without delving into the complex detail of requirements in individual test standards, the paper introduces the identified low frequency and high frequency EMC phenomena that have been covered in the new IEC 1000 series of documents, both from the points of view of emission and immunity. The impact of these disturbances on low voltage protection equipment such as moulded case circuit breakers and earth leakage circuit breakers in particular are examined, but the principles are applicable to all equipment connected to the low voltage installation. The phenomena of transient surges and harmonics together with their effects on performance and survival of connected equipment are given particular attention.

INTRODUCTION

Over the past decade many papers have been written on the subject of EMC (Electromagnetic Compatibility), with discussions being driven by the need to comply with the EC Directive on EMC, which became a mandatory requirement for all goods sold in Europe after January 1 1996. Outside Europe, few countries have such regulations in place, so unless product is exported to Europe, there is not much incentive to address the problems of electromagnetic emission by products or systems. Similarly, the question of a product or system's immunity to the effects of disturbances on the electricity supply network only receives attention after malfunctions have been experienced. Electromagnetic interference phenomena, which have been associated with broadcasting and telecommunications industries in the past, are now of increasing concern to power system engineers. In recent times a proliferation of articles and discussions on the subject of "Quality of Supply" have captured the interest of power system engineers, but often without addressing the growing need for engineers outside of the electrical utilities industry to understand even the basic concepts and need for electromagnetic compatibility (EMC) in low voltage systems.

QUALITY OF SUPPLY

Electricity Supply Utilities are particularly conscious of the Quality of Supply (QOS) of the product that they deliver to their bulk consumers. In theory, regulations on the quality of supply of electricity delivered, are applicable up to the point of consumption of ALL consumers. However, little attention is usually given beyond the high and medium voltage networks. It is unusual to regulate supply quality on the low voltage system outside of the limits that are applied to voltage and frequency deviations. By definition, QOS applies to all aspects of EMC, with the most visible phenomena being Voltage Dips or Depressions and Harmonics. In South Africa, quality of supply standards for application in the Electricity Supply Industry are documented in the Rationalized User Specification NRS 048 : 1996.

In recognition of the high incidence of lightning activity in many parts of South Africa, there is an opinion in some quarters that at the very least, some minimum degree of control on the amplitude of voltage surges arriving at the low voltage point of supply is necessary. Furthermore, since solidly earthed low voltage distribution systems are recommended in NRS 048, some mention of earthing system requirements appears to be appropriate. The debate on these issues continues.

WHAT is EMC ?

Electromagnetic Compatibility (EMC) is achieved when the operation of equipment or products -

- *Is* **unaffected** *by the operation of other equipment.*
- *Results in* **no adverse effects** *on other equipment.*

Electromagnetic Interference (EMI) with the operation of products or systems *is the reason for the need for Electromagnetic Compatibility.*

EMC requirements are commonly divided into :

- *Low frequency phenomena*
- *High frequency phenomena*
- *Electrostatic phenomena*

One unfortunate consequence of modern technology is that power supply networks and the electromagnetic spectrum are being polluted with unwanted signals ranging from d.c. through to high frequencies approaching those of visible light.

Both low frequency and high frequency disturbances are divided into *conducted* and *radiated* disturbances.

Electromagnetic compatibility is the discipline which attempts to overcome, or at least minimise the effects of mismatch between equipment and the operating environment in accordance with agreed standards and regulations.

ELECTROMAGNETIC DISTURBANCES

The principal disturbances in the electromagnetic spectrum are generally classified as follows :

PHENOMENON	DISTURBANCE
Conducted low frequency	*- Harmonics, Interharmonics* *- Signalling Voltages* *- Voltage amplitude variations* *- Voltage Dips* *- Voltage interruptions* *- Voltage unbalance* *- Power frequency variations* *-Induced low freq. voltages* *- d.c. in a.c. networks*
Radiated low frequency field	*- Magnetic fields* *(continuous or transient)* *- Electrical fields*
Conducted high frequency	*- Induced voltages or currents* *- Unidirectional transients* *- Oscillatory transients*
Radiated high frequency	*- Magnetic fields* *- Electric fields* *-Electromagnetic fields* *(continuous or transient)*
Electrostatic discharge	(ESD)
High altitude nuclear electromagnetic pulse	(HEMP)

The phenomena identified as having the greatest impact on the performance of equipment connected to the low voltage system have been addressed and included in the test requirements of the relevant product standards. There are however some phenomena that remain under consideration whilst the importance of their impact is being assessed. These include :

- Induced low frequency voltages
- Electric fields
- High altitude nuclear electromagnetic pulse

WHY IS THERE CONCERN ?

The use of electronically powered and controlled equipment, devices and appliances in large industries or by individuals in residential, commercial or industrial environments, has resulted in a dramatic increase in the generation of interference signals that are polluting the low voltage networks. The effects of EMI are of concern because of the consequential malfunction of key electrical and electronic systems. Such systems could include for example, manufacturing industries, telecommunication services and defence systems. In the extreme, public health and safety could be threatened.

Outside of exporters to Europe, only limited recognition of the problems associated with EMC exist, and little attention is given to the subject.

SPECIFICATIONS and STANDARDS

The one organisation that has been most actively involved in the development and preparation of Standards and publications covering EMC, is the International Electrotechnical Commission (IEC). The IEC has defined three types of Standards. These include :

- Basic standards
- Generic standards
- Product standards

Much of the original IEC work on radiated emission has been based on publications developed by CISPR which is the IEC’s international special committee on radio interference. In addition, several ANSI/IEEE publications have been used as source references in defining the wave shapes of transient surge voltage and current. Basic EMC standards and reports are produced by IEC technical committee TC77 and its sub-committees. The EMC test requirements contained in IEC product standards are determined by the individual IEC product committees, sometimes using also generic standards that cover particular product groups. Where already existing product test requirements can be shown to cover certain EMC tests, these are not required to be repeated. Particular examples worthy of mention, are the short circuit and other overcurrent tests that are applied to circuit breakers. These are deemed to cover the effects of *radiated magnetic fields*.

IEC EMC Standards

The initial serious work on EMC standards within the IEC began in the early 1980’s with the publication of two separate sets of documents, prepared by different IEC technical committees. These included the IEC 801 series of documents prepared by Technical committee TC 65, and the IEC 555 series of documents prepared by technical committee TC77.

IEC 801 covered EMC for industrial process measurement and control equipment.

IEC 555 dealt with disturbances in supply systems caused by household appliances and similar electrical equipment.

Largely driven by more pressing demands of the EC directive on EMC, both IEC 801 and IEC 555 series of documents have been replaced by the new **IEC 1000** series of documents.

For the present, IEC 1000 is divided into six separate parts, and further subdivided into sections which are being published either as International Standards or as Technical Reports.

Part 1	*General*	*- Introduction* *- Fundamental principles* *- Definitions* *- Terminology*
Part 2	*Environment*	*- Description of the environment* *-Classification of the environment* *- Compatibility levels*
Part 3	*Limits*	*- Emission limits* *- Immunity limits*
Part 4	*Testing and measurement*	*- Measurement techniques* *- Testing techniques*
Part 5	*Installation & mitigation*	*- Installation guidelines* *- Mitigation methods & devices*
Part 6	*Generic*	*Generic Standards*

EMC Immunity Test Standards

A number of Basic Standards covering EMC Immunity requirements have been produced by IEC TC77 and it's sub-committees under the banner of the new IEC 1000-4 series of documents. The following list indicates the current status of these IEC **Immunity** test publications:

Standard	Publ	Subject / Test
1000-4-1	1992	*Overview of Immunity tests*
1000-4-2	1995	*Electrostatic Discharge tests*
1000-4-3	1995	*Radiated, radio frequency, electromagnetic field immunity*
1000-4-4	1995	*Fast transient/burst immunity tests*
1000-4-5	1995	*Surge Immunity test*
1000-4-6	1996	*Immunity to conducted disturbances induced by r.f. fields*
1000-4-7	1991	*General guide on Harmonics and Inter-harmonics*
1000-4-8	1993	*Power frequency magnetic field immunity*
1000-4-9	1993	*Pulsed magnetic field immunity*
1000-4-10	1993	*Damped oscillatory magnetic field immunity*
1000-4-11	1994	*Voltage dips, short interruptions and voltage variations*
1000-4-12	1995	*Oscillatory waves immunity test*
1000-4-13	#	*Harmonics, Inter-harmonics and mains signalling immunity*
1000-4-14	#	*Voltage fluctuations*
1000-4-16	#	*Immunity to Conducted disturbance*
1000-4-17	#	*Ripple on d.c. power supply*
1000-4-28	#	*Variation of power frequency*
		# Still in preparation

EMC STANDARDS FOR RCD'S

The EMC requirements for RCD's (known as ELCB's in South Africa and GFI's in the USA) have been covered in the relatively new standard IEC 1543 which was published in April 1995.

IEC 1543 is one of the better examples of consolidated work on EMC within the IEC. It addresses both emission and immunity requirements for Residual Current Devices. Whilst IEC 1543 has been directed specifically at RCD's for household and similar use, it's value has been recognised by other IEC committees and it is already being used as a reference document for the updating of EMC requirements for similar devices covered in IEC 947-2 - Circuit Breakers. For SAFETY products such as residual current circuit breakers, the possible problems that could result from electromagnetic interference are of particular concern. At best, such interference can lead to unwanted tripping of the RCD. At worst, the RCD could malfunction in the presence of extraneous radiated or conducted signals. Several decades of installation and application experience with millions of RCD's in a variety of installation environments has assisted manufacturers of these devices in identifying most of the application problems that can arise due to disturbances in the electrical supply network.

During the preparation phase of EMC standards for RCD's, it was realised that at least some of the existing performance tests that had been included in the RCD product standards, already addressed a portion of the generalised EMC test requirements.

In general these are included in the low frequency EMC immunity requirement.

The following are deemed to be covered by existing test requirements in the RCD product standards:

- Voltage fluctuation
- Voltage dips
- Voltage interruptions
- Voltage unbalance
- Power frequency variations

In recognition of the specific safety functions of RCD's, and independent of the need created by the implementation of the EC directive on EMC, IEC 1543 was produced to deal with the EMC aspects that had already been identified through the application and operation of RCD's. This International Standard includes definitions, standard electromagnetic conditions, conditions of operation in service and electromagnetic tests necessary for devices providing residual protection. The framework of the document was based on recommendations given in the IEC 1000 series of documents. The existing performance tests that had been deemed to cover some of the low frequency EMC immunity tests were then "plugged-in" to the framework. The document was completed using wherever possible, the work completed and in progress in the IEC 1000 series.

EMC Emission of RCD's

As a general rule within the IEC, it has been determined that for equipment not incorporating electronic circuits, electromagnetic disturbances can only be generated by equipment during occasional switching operations. The duration of these disturbances is of the order of milliseconds. The IEC has concluded that the consequences of these emissions are relatively insignificant and can be considered as part of the normal electromagnetic environment of low voltage installations. Therefore in such cases the requirements for electromagnetic emission are deemed to be satisfied and no verification is necessary. Emission tests according to CISPR 14 are however required for those RCD's that contain continuously operating oscillators and/or microprocessors.

Performance criteria of RCD's

The performance criteria that are used to determine the immunity of RCD's to the effects of electromagnetic interference are based on :

- *Freedom from nuisance tripping*
- *Non-interference with the ability of the RCD to perform it's safety functions.*

Surge Voltages and Surge Currents

The propagation of voltage and current surges in low voltage wiring systems are of particular concern to consumers of electricity in considering :

- *Insulation co-ordination in the fixed wiring*
- *Damage to fixed equipment and appliances*
- *Maloperation of equipment and processes*

One of the most visible effects of mains borne lightning or switching surges is the unwanted tripping of RCD's. Voltage surges or Current surges that result from induced voltages can cause nuisance tripping in RCD's due to :

- *Insulation sparkover in the fixed installation*
- *Insulation sparkover in appliances*
- *Voltage stress on components within the RCD*
- *Spurious response of the RCD to non-damaging current surges.*

In ideal situations where overvoltage control is employed together with good insulation co-ordination, insulation sparkover should not be a problem. This however is not always the case, and RCD's are required to be immune to the effects of surge currents that do not result in any permanent damage to connected equipment. Immunity to surge currents in RCD's is achieved in the main through two standardised test procedures which include :

- *Current oscillatory transients*
- *Unidirectional surge currents*

Current Oscillatory transients

RCD's are tested using a surge current generator capable of delivering a damped oscillatory current of 200A peak. The current wave is based on the original voltage wave that was proposed in ANSI/IEEE C62.41-1980 (see Figure 1.)

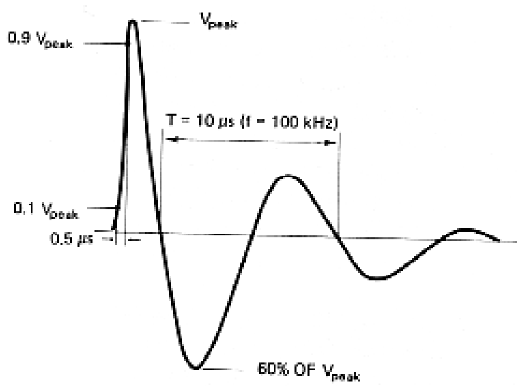

Figure 1 - Ring Wave

Based on measurements that were conducted by several independent organisations in both Europe and the USA, this so-called 0,5 microsecond - 100kHz "ring wave" is now considered to be reasonably representative of surge voltages appearing on indoor low voltage power circuits.

Unidirectional surges

In the outdoor and service entry environment, as well as in locations close to the service entrance, substantial energy or current is still available. For these locations the long established unidirectional impulses are considered to be more applicable than the oscillatory wave. The amplitude of the impulse voltage for testing RCD's according to IEC 1008 is 5kV peak common mode and 4kV peak in differential mode.

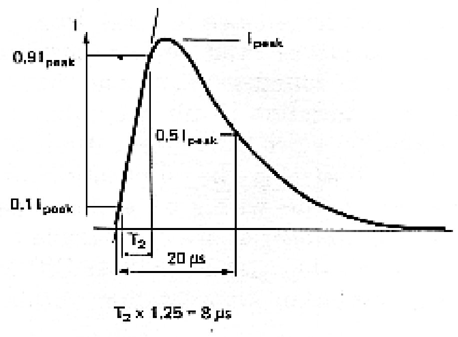

Figure 2 - Discharge current waveform

In the case of RCD's where a higher degree of immunity to current surges is required, a surge current having a wave shape of 8/20 microseconds as shown in Figure 2 is used. The amplitude of the current surge is determined by the specified surge generator impedance. Generator impedance is specified as 12 ohms for the common mode test and 2 ohms for the differential mode test.
The 8/20 microsecond *Current* surge is derived from the 1,2/50 microsecond *Voltage* surge which is shown in Figure 3.

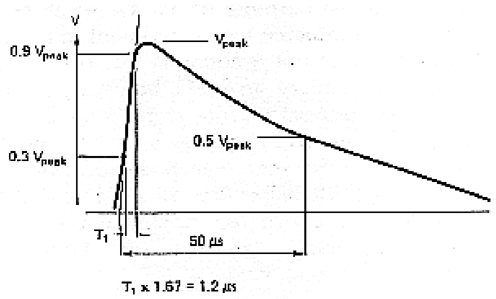

Figure 3 - Open - Circuit Waveform

Insulation Testing
It has been long established that the application of unidirectional impulse voltages of the 1,2/50 microsecond waveshape are very effective in establishing the dielectric withstand capabilities of electrical switchgear. For certain applications, impulse voltage testing is even replacing some power frequency dielectric testing requirements.
It is unfortunate that in some areas, there remains confusion between EMC surge tests and these dielectric tests which are *Impulse Voltage tests*, without any need for consideration of surge currents resulting from the voltage impulse.

Radio frequency Electromagnetic fields
Within the IEC 1000 series there are two separate documents that deal with the question of Radio Frequency electromagnetic field immunity tests.
IEC 1000-4-3 covers *RADIATED* r.f. fields.
IEC 1000-4-6 covers *CONDUCTED* r.f. fields.
In both cases, the source of the disturbance is basically an electromagnetic field, originating from intended r.f. transmitters that may act on the whole length of cables connected to an installed equipment.
The dimensions of disturbed equipment such as RCD's are small compared with the wavelengths involved. The incoming and outgoing leads will therefore behave as passive receiving antenna networks since they can be several wavelengths long. The scope of IEC 1000-4-6 covers the frequency spectrum of 9kHz up to 80MHz. For small devices such as RCD's, it may be possible in the future, to test according to IEC 1000-4-6 for *Conducted* radio frequency fields up to 230 MHz.
The test levels for RADIATED radio frequency electromagnetic field tests for RCD's are taken from IEC 1000-4-3 for the frequency spectrum 80MHz up to 1000MHz. This radiation is often generated by such sources as small hand held radio receivers as well as fixed and mobile radio and television transmitters.
The question of emission due to GSM digital radio telephones is still under investigation by the relevant IEC sub committee.

Electrical fast transient bursts
In addition to the voltage and current impulse tests that are applied to RCD's, it has been found to be appropriate to include tests to demonstrate the immunity of RCD's to transient disturbances such as those originating from switching transients, including the interruption of inductive loads and relay contact bounce etc. The IEC Basic EMC publication IEC 1000-4-4 includes tests for this condition, establishing a common and reproducible basis for evaluating the performance of equipment when subjected to repetitive fast transient bursts on supply, signal and control ports.
It has been determined that for RCD's, test level 4 is appropriate for common mode testing, with a 5/50 nanosecond pulse having a voltage peak of 4kV and a repetition rate of 2,5kHz.

Electrostatic Discharge Immunity Tests

IEC 1000-4-2 establishes a common and reproducible basis for evaluating the performance of electrical and electronic equipment when subjected to electrostatic discharges (ESD), including those which may occur from personnel to devices such as RCD's. For RCD's, IEC 1543 requires IEC 1000-4-2 test level 3 which specifies 6kV contact and 8kV air discharge. Contact discharge is applied to conductive surfaces and air discharge at insulating surfaces.

It is important to note that in accordance with the requirements of IEC 1000-4-2, the static electricity discharges are applied *only* to such points and surfaces of the RCD (or any equipment), which are accessible to personnel during *normal usage*.

Harmonics

Harmonics are sinusoidal voltages having frequencies that are whole multiples of the frequency at which the supply system operates. Harmonic disturbances are generally caused by equipment with non-linear voltage/current characteristics or by periodic and line-synchronised switching of loads. As a result of cable transfer capacitance, line inductance and connection of power factor correction capacitors, parallel and series resonances may occur in the network and cause a voltage amplification even at remote points from the distorting load. Summation of the effects of harmonics are likely and must be considered.

The presence of harmonics in low voltage electrical supply systems has been recognised for many years. It is however only in relatively recent times, that the proliferation of harmonic producing devices has increased to the extent that some serious attention needs to be given to the problem. Not generally appreciated is the fact that household television receivers are one of the most prolific generators of harmonics. A further irony is that energy efficient self ballasted fluorescent lamps produce high levels of third harmonic currents.

For consumer generated harmonics, harmonic *currents* predominate, and are aggravated in conditions where harmonic producing loads are large in comparison to the supply capacity. It is unfortunate that users are often misled by regulations that permit reduced sized neutral conductors. The increased neutral currents that result directly from the presence of harmonics should always be taken into account before any consideration is given to reduced neutrals. In many applications it is becoming increasingly necessary to allow for increased neutral currents and to overrate cables and switchgear accordingly. The presence of power factor correction capacitors often aggravates the effects of harmonics, which are generally observed in the form of overheating and data corruption. Damage due to increased voltage stress is also becoming more common.

CONCLUSIONS

It is obvious that this paper in the main, has addressed the question of electromagnetic compatibility in Residual Current Devices that are intended for Shock Hazard and Fire Hazard protection. Most of the information presented is however generic, and can be applied not only to the fixed low voltage installation, but also to most equipment and appliances that are connected to the low voltage supply system. The importance of understanding the implications of electromagnetic interference and the need to consciously put in place programs that will reduce the degree of electrical pollution that exists in our supply networks cannot be overstated.

In developing societies such as South Africa with its massive electrification program, the residential usage of electricity will become far greater as a percentage of total electricity usage. The combined pressures of cost and appliance technology are bound to ensure that whatever EMC problems already exist today, these can only become worse. We all need to be proactive in dealing with EMC without introducing the cost implications of over specification. We ignore EMC at our peril !

REFERENCES

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