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TECHNICAL REPORT

Standardising the characteristics of electricity

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STANDARDISING THE CHARACTERISTICS OF ELECTRICITY

FOREWORD

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IEC 62510, which is a technical report, has been prepared by IEC technical committee 8: Systems aspects for electrical energy supply.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
8/1226/DTR	8/1248/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

While standards exist in various countries for some of the characteristics of electricity supplied from public networks, IEC 61000-2-1, 1990, EN 50160 and IEEE 1159 are attempts to cover all of the characteristics more or less comprehensively. EN 50160 was a response to a formal declaration that electricity is a product – according to European Directive 85/374/EEC concerning liability for defective products.

The network operators have the responsibility of designing and operating the network with the required level of quality which may be defined by national laws, national or international standards.

The following text describes the nature of electricity and the relation between quality of supply and EMC. It is taken very largely from the EURELECTRIC PQ Report, 2nd Edition.

Quality of supply

Of all the basic services on which modern society relies for support, electricity supply is one of the most essential. In order to provide that support, several qualitative aspects are significant.

a) Constant availability is an important requirement, involving
   - for continuity of supply in day-to-day terms, an operating regime whereby the inevitable supply interruptions are prevented from being either unduly prolonged or unduly frequent;
   - for more long-term security of supply, a stable balance between user demand and the availability of generation, transmission and distribution assets as well as energy sources.

b) The utilisation of electricity requires both voltage and frequency to be standardised in order that the supply as delivered to the user is co-ordinated with the equipment by which it is utilised. It is very important to maintain the supply within reasonable range of the standard values that are adopted for voltage and frequency.

c) Notwithstanding acceptably stable levels of voltage and frequency, there are several quite short-term, low-amplitude or occasional irregularities superimposed on the voltage that can hinder the proper functioning of electrical equipment within manufacturers installations or on the electricity network itself.

NOTE There have been many different approaches to classifying the qualitative aspects of electricity supply, complicated further by the current practice of separating the functions of generation, supply, network operation, etc. For example, a recent report by the Council of European Electricity Regulators uses the following terms:

– ***commercial quality:*** concerning the business relationships between suppliers and users with respect to how well the various services are delivered (The services concerned are not confined to network operation);

– ***continuity of supply:*** concerning the extent to which customers find that their electricity supply is interrupted for various reasons – see a) above;

– ***voltage quality:*** concerning the technical characteristics of the supply with respect to the voltage delivered to customers, i.e. its magnitude and frequency, as in b) above, together with the potentially disturbing aspects referred to in c) above.

STANDARDISING THE CHARACTERISTICS OF ELECTRICITY

1 Scope

This technical report outlines the way in which electricity is now described as a product. Particularly, in Europe and several other areas, for example Brazil and Argentina, as well as in some states in the United States of America.

It is, however, rather a unique product because of its intangible and transient nature. Strictly, it is a product that exists only for an instant at a given point of delivery, comes into existence at the same instant at which it is being used and is replaced immediately by a new product with rather different characteristics. Its characteristics are different at each separate point of delivery. Moreover, it is a product whose quality depends not only on the elements that go into its production, but also in the way in which it is being used at any instant by the equipment of multiple users.

Therefore, the quality control that is possible for more tangible and concrete products is not applicable in the case of electricity. All that can be attempted is some control of the conditions under which it is produced, transmitted and distributed and those under which it is used. In particular, the capacity of utilisation equipment to impinge on the quality of electricity, including that delivered to other equipment, must be recognized.

Electrical equipment has become increasingly complex in terms of the functions it fulfils and the way in which it interacts with other electrical equipment. Frequently, that interaction takes place through the medium of the electricity network, which is the common energy source for all the equipment. It arises because the network, intended to be a common energy source, also provides a conducting path interlinking all equipment.

In effect, the electromagnetic phenomena arising from the behaviour of utilisation equipment are superimposed on the other characteristics of the electricity supply, and become part of the product that is delivered to the system user. They are joined also by phenomena arising from atmospheric and other external events and from the intrinsic response of a large electricity system to such events.

2 The power quality phenomena

Observation of normalized network impedance characteristics, such as proposed in IEC 60725 for 16 A and 75 A supplies, is essential so that electricity suppliers, distributors and system users can share the power quality responsibility.

NOTE Normalized network impedances are not always applicable in many countries, because the particular network configuration makes the power quality management easier and more reasonable by using other methods rather than normalized network impedances.

The degree of economic development has a great influence on the importance attached to the different elements of supply quality. At an earlier stage of development, the primary concerns are likely to be that electricity is actually available and, when available, that the voltage and frequency are within reasonable range of their nominal values for most of the time. When these are the primary concerns, such matters as voltage dips, transients, etc. are seen as having minor relevance. With more advanced economic development, however, continuity, voltage and frequency, while remaining important, begin to be taken for granted, and the emphasis shifts to the set of phenomena encompassed by the modern term, “power quality”. These phenomena are briefly described below.

Harmonics, interharmonics and frequencies in the range of 2 kHz to 9 kHz: these arise mainly from system users' equipment that draws a current not linearly related to the voltage, thereby injecting currents at unwanted frequencies into the supply network.

Flicker, as a main effect of voltage fluctuations, which are caused by system users' equipment drawing current of fluctuating magnitude, resulting in corresponding fluctuation of the voltage on the network.

Short duration RMS variation (instantaneous, momentary, and temporarily): these are caused by the sudden occurrence and termination of short circuits, motor starts or other current increase on the supply system or installations connected to it.

Transient overvoltages (Impulsive and oscillatory): several phenomena, including the operation of switches and fuses and the occurrence of lightning strokes in proximity to the supply networks, give rise to transient overvoltages in distribution networks and in the installations connected to them.

Temporary power frequency overvoltages and undervoltages (long duration RMS variations): depending on the utilities practices, temporary power frequency overvoltages between live conductors and earth occur often as a consequence of a neutral conductor interruption. A temporary power frequency overvoltage may also appear during an earth fault in the public distribution system or in a customer's installation and disappears when the fault is cleared.

Harmonics: these frequencies are integer (multiple) of the fundamental frequency.

Interharmonics: between the harmonics of the power frequency voltage and current, further frequencies can be observed which are not integers of the fundamental. They can appear as discrete frequencies or as a wide-band spectrum. They arise from the operation of non-linear loads as frequency converters, rectifiers and similar control equipment.

Unbalance: unbalanced voltages on three-phase systems arise from a failure or inability to keep the currents drawn by system users' equipment evenly balanced between the phases.

3 The need to manage the characteristics of electricity

The above characteristics of the voltage are unwanted and constitute defects in the product, electricity. Yet they are absolutely intrinsic in the supply and utilisation of electricity as a public utility. Since they cannot be eliminated, the practical requirement is to manage them in a proper way, which may differ from one phenomenon to another. This management task is one to be undertaken jointly by electricity generators, network operators and manufacturers.

These phenomena have the potential of hindering or limiting the operation of electrical equipment, either on the public network itself or, more often, within the installations of system users. They are therefore referred to as disturbances, and end user's equipment that is causing disturbances, is referred to as a disturbing load.

4 Connection of loads and generators

Throughout the century-old history of public electricity supply, network operators have always sought to control the connection of loads to the network in order to maintain a certain stability of frequency and voltage and a low level of disturbances on the network. It is usually a condition of supply to all system users that they avoid disturbing the operation of the network or the supply to other network users. When the load is part of a large installation, the relevant details are declared to the network operator before the connection is provided. This gives the network operator the opportunity to design a suitable method of supply and agree an acceptable operating regime with the network user, in conjunction with his equipment provider and other expert advisors. In that way, the level of the disturbance can be maintained at an acceptable level.

For instance, in the case of harmonics, distortion was kept to quite low levels on almost all networks – lower than the values specified in the IEC compatibility levels and EN 50160.

In more recent decades, disturbances are being generated to an increasing extent by small-load devices that network users purchase on the retail market and install without reference to the network operator. They include IT and other electronic devices, such as television receivers, personal computers, etc. These devices are small users of electricity and the level of the disturbance is correspondingly small in absolute terms. They are installed in very great numbers, however, and there is frequently a high level of simultaneity in their operation. Consequently, the cumulative level of the disturbance generated by them can be quite high. Since they are installed without reference to the network operator, they avoid the control system that has existed since the start of public electricity supply, as described above. Indeed, the disturbing devices are far too numerous to be considered individually. It was in recognition of the greater difficulty of control, coupled with the realisation that voltage levels at unwanted frequencies were already rising due to television receivers and other electronic devices, including PCs, that the comparatively high compatibility levels were specified, reflected also in EN 50160.

In the future, distributed generation will have a great impact in terms of stability of the voltage, fundamental frequency and disturbances. For the smallest units, available on the retail market, they will be installed without reference to the network operator, which depends on each different country, they will also avoid the control system that had existed since the start of public electricity supply, as described above. Indeed, those types of devices will be far too numerous to be considered individually.

Yet, it remains the obligation of the network user, except for household appliances users, to avoid generating excessive disturbance. The only means by which the user can fulfil this obligation is by having equipment available which, by its design and construction, moderates the generation of disturbance to an adequate degree.

5 The contribution of electromagnetic compatibility (EMC)

The design and construction of equipment that fulfils both those needs is the goal of the EMC process in IEC and CENELEC. Electromagnetic compatibility is defined as *the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.* Therefore, EMC seeks what is sought also for the utilisation of electricity by users' appliances, namely, that the generation of disturbance must be limited and equipment must be capable of tolerating a reasonable level of disturbance. Of course, EMC extends also to equipment that is not connected to the electricity network and to electromagnetic phenomena that are not relevant to those networks.

The EMC family of documents in the IEC 61000 series includes standards establishing limits for both, the *emission* of and *immunity* from disturbance, as well as numerous other supporting standards, reports, etc. describing the electromagnetic environment and phenomena found in it, methods of measurement and test, mitigation, etc. Among them are standards for *compatibility levels,* which are reference values established to enable emission and immunity limits to be co-ordinated with each other and with the actual disturbance levels to be expected or regarded as acceptable in the various environments.

That relation between compatibility levels and the levels of disturbance in the actual environment, in the case of low frequency conducted phenomena, is the reason for the close correspondence between the compatibility levels and the levels specified in EN 50160. Equally, if the measured disturbance levels are found to exceed or be very close to those levels that are a cause for concern about whether the emission limits are sufficiently low or are being applied sufficiently strictly. Moreover, if electricity users' equipment is actually being disturbed by one or other of the phenomenon, that raises the question of whether the immunity limits are adequate or are being applied properly.

Therefore, the quality of the electricity supply is very dependent on the EMC process, and requires suitable limits properly applied. If the EMC process is effective, then disturbances emitted by equipment connected to the networks are controlled so that supply quality is not unduly affected, and the equipment is capable of continuing to function as intended despite the disturbances arriving via the network. While EMC is not concerned directly with the safety of equipment, securing the intended operation of equipment automatically avoids its being damaged.

6 Coordination of the parties involved

In relation to supply quality, three different relations are to be considered:

- network operator – electricity consumer,
- electricity consumer – equipment supplier
- network operator – equipment supplier.

6.1 Network operator – final customer

The quality of the supply involves two parties directly, the network operator and the final customer.

a) For the electricity delivered at the supply terminals, it is up to the network operator to take all practical steps to ensure that its characteristics remain within such limits as are specified and to inform, if required, the customer of the levels that can occur in normal operating condition (the customer needs also to be aware that abnormal conditions occur occasionally). To fulfil the above responsibility, the network operator is also obliged to maintain reasonable control of the way in which all customers use the electricity, and to provide each customer with such network information as may be necessary to enable him to use the supply without disturbance to others.

b) The responsibility of the customer is to use the electricity in a way that avoids disturbing the operation of the network or the supply to other users and, insofar as such disturbance arises, to take all necessary steps to reduce it to an acceptable level. That responsibility of the customer includes providing the network operator with all information reasonably requested regarding the equipment that is or will be installed and the way in which it will be operated. Further, the customer has to comply with such conditions for its operation as may be specified by the network operator to prevent the emission of disturbance at an excessive level.

   NOTE For practical reasons, this responsibility is fulfilled in this way only for relatively large loads and installations. In relation to other equipment, the quality of the supply, avoidance of disturbance and proper functioning of the networks and users' equipment are dependent on the proper implementation of the EMC process.

6.2 Final customer – equipment supplier

Under normal conditions, the final customer uses electricity by means of electrical equipment. The supplier of that equipment is indirectly involved in the relationship between customer and network operator.

a) The equipment supplier ensures that the equipment can perform the intended function, including avoidance of disturbance, and is suitable for the electromagnetic environment in which it is intended to operate, including the conditions that can arise in public electricity supplies.

b) The equipment supplier is further responsible to provide the consumer with such information about the characteristics of the equipment as may be required for transmission to the network operator or the instruction of the customer.

   NOTE Safety considerations in case of normal and abnormal conditions of the network are not dealt with in this technical report.

6.3 Network operator – equipment supplier

Finally, at representative level, both network operators and equipment manufacturers are jointly involved in the EMC process, in order to ensure that

a) emission limits are such as to prevent disturbance levels on electricity networks rising to values that would hinder or limit the proper functioning of electricity users' equipment or the proper operation of the electricity networks;

b) electricity users' equipment is provided with adequate immunity from the disturbances that can be transmitted via the supply terminals at the levels that can be found in practice.

NOTE While the concern of EMC is to secure the intended operation of equipment, it is clear that the consumer also requires that his equipment should not be damaged. If operation as intended is secured, that normally would be presumed to prevent damage also.

7 Share of the work in the standardisation bodies

Previously, SC 77A was in charge of EMC limits for mass equipment which are one of the major sources of the disturbances on the network. This task remains in the scope of IEC SC 77A because it is essentially an issue dealing with EMC even if it has an impact on the power quality of the networks. In addition, SC 77A published in the past two technical reports, IEC 61000-3-6 and IEC 61000-3-7 which provide the methods of assessment of disturbances created by an installation. These two technical reports are relatively old but are to be maintained according to the feedback of their use. This maintenance task has been initiated by a wide audience, as it was done in the past for these documents, by the starting of a CIGRE-CIRED Working Group with the participation of IEEE, IEC, UIE and EURELECTRIC.

SC 77A is providing assistance to TC 8 on this matter by publishing:

– assessment methods of harmonic emission per installation;
– assessment methods of voltage fluctuations (flicker) per installation;
– assessment methods of unbalance per installation.

These documents will be used to define the limits per installation.

In addition, IEC 61000-4-30, prepared by SC 77A, and recently published describes the different power quality measurement methods.

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IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

EN 50160, *Voltage characteristics of electricity supplied by public distribution networks*

IEEE 61159, *Recommended practice for monitoring electric power quality*

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