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Electromagnetic compatibility (EMC) - Part 3: Limits - Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems - Basic EMC publication

Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3: Limits – Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems – Basic EMC publication

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Standardization Organization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

IEC 1000-3-7, which is a technical report of type 3, has been prepared by sub-committee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

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

Committee draft	Report on voting
77A/136/CDV	77A/154/RCV

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 report is a technical raport of type 3 and is of a purely informative nature. It is not to be regarded as an International Standard.

INTRODUCTION

This technical report is part of the IEC 1000 series, according to the following structure:

Part 1: General

General considerations (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 (in so far as they do not fall under the responsibility of product committees)

Part 4: Testing and measurement techniques

Measurement techniques
Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines
Mitigation methods and devices

Part 6: Miscellaneous

Each part is further subdivided into sections which are to be published either as international standards or as technical reports.

This section is a technical report.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3: Limits –
Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems –
Basic EMC publication

1 Scope

This technical report outlines principles which are intended to be used as the basis for determining the requirements for connecting large fluctuating loads (producing flicker) to public power systems. The primary objective is to provide guidance for engineering practices which will ensure adequate service quality for all connected consumers.

Since the guidelines outlined in this report are necessarily based on certain simplifying assumptions, there is no guarantee that this approach will always provide the optimum solution for all flicker problems. The recommended approach should be used with flexibility and judgment as far as engineering is concerned, when applying the given assessment procedures in full or in part.

The final decision regarding the connection of fluctuating installations will always rest with the utility.

Problems related to voltage fluctuations fall into two basic categories:

– flicker effect from light sources;
– risk of the voltage magnitude being outside accepted tolerances.

This report primarily focuses on controlling or limiting flicker, but a clause is included to address voltage magnitude changes and their effects.

NOTES

1 This report uses the following terms for system voltage:

– low voltage (LV) refers to		U_N	≤ 1 kV;
– medium voltage (MV) refers to	1 kV <	U_N	≤ 35 kV;
– high voltage (HV) refers to	35 kV <	U_N	≤ 230 kV;
– extra high voltage (EHV) refers to	230 kV <	U_N.	

In the context of this report, the function of the network is more important than its rated voltage. For example, a HV system used for distribution may be given a "planning level" (see clause 3) which is situated between those of MV and HV systems.

2 The "load" is to be understood as the complete consumer's load.

2 Reference documents

IEC 50(161): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 868: 1986, *Flickermeter – Functional and design specifications*

IEC 1000-3-3: 1994, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A*

IEC 1000-3-5: 1994, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 5: Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16 A*

3 Basic concepts

The international flickermeter (see IEC 868) provides two quantities to characterize the flicker severity: P_{st} ("st" referring to "short term": one value is obtained for each 10 min period) and P_{lt} ("lt" referring to "long term": one value is obtained for each 2 h period). The flicker related voltage quality criteria are generally expressed in terms of P_{st} and/or P_{lt}, P_{lt} being derived from groups of 12 consecutive P_{st} values:

$$P_{lt} = \sqrt[3]{\frac{1}{12} \cdot \sum_{j=1}^{12} P_{st\,j}^{3}} \qquad (1)$$

Flicker measurements are generally made at the point of common coupling (PCC) of a fluctuating load, i.e. at the MV or HV level in the context of this report. However, it should be remembered that the background for limits is the possible annoyance of LV consumers. It is assumed that the flickermeter is adapted to the voltage of the lamps so that the same limits apply irrespective of the voltage of the LV distribution system. This is important because 120 V lamps are less sensitive to voltage fluctuations than 230 V lamps and 100 V lamps are even less sensitive (see figure 4).

Emission limits for individual equipment or a consumer's total load should be developed on the basis of voltage quality criteria. Some basic concepts are used to evaluate voltage quality. In order for these concepts to be useful in meaningful evaluation, they are defined in terms of where they apply (locations), and how they are measured (measurement duration, sample times, averaging durations, statistics), and calculated. These concepts are described here and illustrated in figures 1 and 2. Definitions may be found in IEC 50(161).

Compatibility levels

These are reference values (see table 1) for coordinating the emission and immunity of equipment which is part of, or supplied by, a supply network in order to ensure the EMC in the whole system (including network and connected equipment). Compatibility levels are generally based on the 95 % probability levels of entire systems using distributions which represent both time and space variations of disturbances. There is allowance for the fact that a utility cannot control all points of a network at all times. Therefore, evaluation with respect to compatibility levels should be made on a system basis and no assessment method is provided for evaluation at a specific location.

The compatibility levels for flicker in LV and MV systems are given in table 1.

Table 1 – Compatibility levels for P_{st} and P_{lt} in LV and MV power systems

	Compatibility levels
P_{st}	1,0
P_{lt}	0,8

Planning levels

These are levels that can be used for planning purposes in evaluating the impact on the supply system of all consumer's loads. Planning levels are specified by the supply utility for all voltage levels of the system and can be considered as internal quality objectives. Planning levels are equal to or lower than compatibility levels. Only indicative values may be given because planning levels will differ from case to case, depending on network structure and circumstances. As an example, see the planning levels for P_{st} and P_{lt} presented in table 2.

Table 2 – Indicative values of planning levels for P_{st} and P_{lt} in MV, HV and EHV power systems

	Planning levels	
	MV	HV-EHV
P_{st}	0,9	0,8
P_{lt}	0,7	0,6

NOTES

1 These values were chosen on the assumption that the transfer coefficient between MV or HV systems and LV systems is unity.

2 In practice, transfer coefficients from HV to LV (T_{PstHL}) are often significantly lower than unity. A typical value for T_{PstHL} is 0,8: in such a case, the indicative planning level for HV becomes L_{PstHV} = 0,8/0,8 = 1,0.

3 The planning levels in table 2 are not intended to control flicker arising from uncontrollable events such as faults in the power system, etc.

The rest of this report outlines procedures for using these planning levels to evaluate connection requirements for individual consumers.

Assessment procedure

Measurements should be carried out according to IEC 868 with a minimum duration of one week. From the P_{st} values measured during the observation week, the Cumulative Probability Functions (CPF) of P_{st} and P_{lt} should be obtained and the percentiles $P_{st95\%}$, $P_{st99\%}$, $P_{lt95\%}$ and $P_{lt99\%}$ should be derived:

– $P_{st99\%}$ should not exceed the planning levels;

– $P_{lt99\%}$ should not exceed the planning levels.

NOTES

4 Comparing 99 % to 95 % percentiles may be useful. If the ratio between them is greater than 1,3 one should investigate the reason for the discrepancy. Possible abnormal results (e.g. due to thunderstorms) should then be eliminated.

5 It is worth noting that, with reference to an observation period of one week, the percentile $P_{st99\%}$ is exceeded for a total time of 1 h and 40 min. Theoretically, a fluctuating load could generate severe flicker continuously for such a period and cause complaints. Experience has shown that load cycles of similar duration occur many times in a week and uncommon load cycles (for example amusement places, etc.) that might take place once a week, usually last for more than 1,5 h to 2 h.

Figures 1 and 2 illustrate the basic concepts described above. They are intended to emphasize the most important relationships between the basic variables.

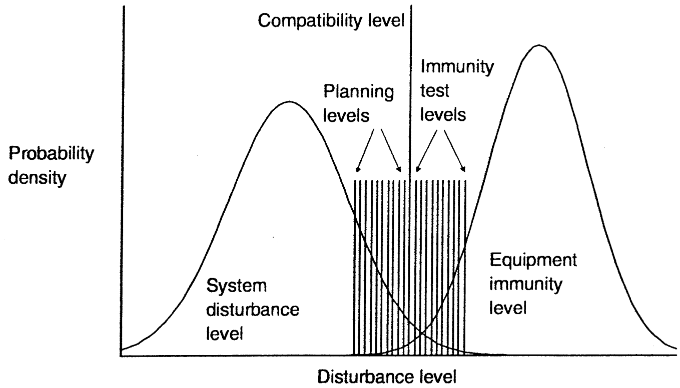

Figure 1 – Illustration of basic voltage quality concepts with time/location statistics covering the whole system

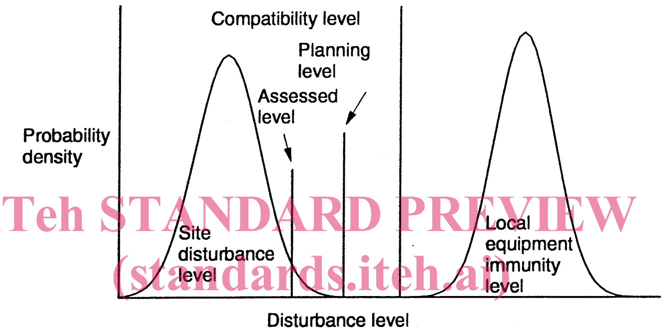

Figure 2 – Illustration of basic voltage quality concepts with time statistics relevant to one site within the whole system

In the whole power system (see figure 1), interference inevitably occurs on some occasions and therefore there is significant overlapping between the distributions of disturbance and immunity levels. Planning levels are generally equal to or lower than the compatibility level; they are specified by the owner of the network. Immunity test levels are specified by relevant standards or agreed upon between manufacturers and users.

At most locations in the power system (figure 2 is just an example), there is no overlap or only a small overlap of disturbance and immunity level distributions; interference is therefore minor and equipment functions satisfactorily.

Emission levels

The emission level from a fluctuating load is the flicker level which would be produced in the power system if no other fluctuating load was present. In order to compare the consumer's total load flicker emission with the emission limits, the minimum measurement period should be one week. From the P_{st} values measured during the observation period, the Cumulative Probability Functions (CPF) of P_{sti} and P_{lti} should be obtained and the percentiles $P_{st99\%i}$ and $P_{lt99\%i}$ should be derived:

– $P_{st99\%i}$ should not exceed the emission limit E_{Psti};

– $P_{lt99\%i}$ should not exceed the emission limit E_{Plti}.

In practice, these emission levels are generally assessed from the available data concerning the load and the system; their direct measurement is however possible.

In the case of a low background disturbance ($P_{st} \leq 0,5$) the flicker level at the PCC should be measured for the following two conditions:

– with the fluctuating load of the consumer connected;

– with the fluctuating load and any compensating equipment of the consumer disconnected.

The second flicker value should be subtracted from the first one using the cubic summation law (see clause 6). This method gives the conventional flicker emission of the user:

When the existing P_{st} level at the PCC is higher than 0,5, a more refined method should be used, as the previous method can lead to gross errors. For example, the net flicker emission of the user can be evaluated by simulating the injection of the consumer's load current into a model of the supply system. Several other methods are possible. Another technical report on this subject is under consideration.

4 General principles

The proposed approach for evaluating the acceptability of fluctuating loads depends on the agreed power of the consumer, the power of the flicker-generating equipment, and the system characteristics. The objective is to limit the injection from the total load of individual consumers to levels that will not result in flicker levels that exceed the planning levels. Three stages of evaluation are defined, which may be used in sequence or independently.

Stage 1: simplified evaluation of disturbance emission

It is generally acceptable for consumers to install small appliances without specific evaluation of flicker emission by the supply company. Manufacturers of such appliances are generally responsible for limiting the emissions. For instance, IEC 1000-3-3 is a product family standard which defines emission limits of flicker for equipment connected to LV systems. There are currently no emission standards for MV equipment for the following reasons:

– medium voltage varies between 1 kV and 35 kV;

– no reference impedance has been internationally defined for medium-voltage systems.

Even without a reference impedance, it is possible to define criteria for quasi-automatic acceptance of consumers on the MV system (and even HV system). If the total fluctuating load, or the consumer's agreed power, is small relative to the short-circuit capacity at the PCC, it should not be necessary to carry out detailed evaluation.

In clause 6, specific criteria are developed for applying stage 1 evaluation.

Stage 2: emission limits proportional to the agreed power of the consumer

If a load does not meet stage 1 criteria, the specific characteristics of the flicker generating equipment should be evaluated along with the absorption capacity of the system. The absorption capacity of the system is derived from the planning levels and is apportioned to individual consumers according to their demand with respect to the total system capacity. At medium voltage, the disturbance level derived from higher voltage systems should also be considered when apportioning the planning levels to individual consumers.

The principle of this approach is that, if the system is fully loaded and all consumers are injecting up to their individual limits, the total disturbance levels will be equal to the planning levels. A procedure for apportioning the planning levels to individual consumers is outlined in clause 7.

Stage 3: acceptance of higher emission levels on an exceptional and precarious basis

Under special circumstances, a consumer may require to emit more disturbances beyond the basic limits (stage 2) allowed. The parties concerned, i.e. consumer and utility may agree on the connection with special conditions and a careful study of the actual and future system characteristics has to be carried out in order to determine these special conditions.

NOTE – Emission limits obtained from the application of the methods recommended in clauses 6 and 7 are intended to keep flicker levels below the planning levels. The application of other methods recommended in clause 8 is intended to limit the magnitude of rapid voltage change.

Responsibilities

The consumer is responsible for maintaining his emissions at the PCC below the limits specified by the utility. The utility is responsible for the overall control of disturbance levels under normal operating conditions in accordance with national requirements.

The utility has to provide network data for evaluation purposes. The evaluation procedure (see figure 3) is designed in such a way that the flicker emissions from the consumers do not cause the overall system flicker levels to exceed the planning and compatibility levels. However, there is no guarantee that the recommended approach will always avoid exceeding the levels.

Finally, the utility and consumer should cooperate when necessary in the identification of the optimum method to reduce emissions. The design and choice of method for such reduction are the responsibility of the consumer.