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Edition 3.0 2012-06

TECHNICAL REPORT

RAPPORT TECHNIQUE

Consideration of reference impedances and public supply network impedances for use in determining the disturbance characteristics of electrical equipment having a rated current ≤75 A per phase

Étude des impédances de référence et des impédances des réseaux publics d'alimentation aux fins de la détermination des caractéristiques de perturbation des équipements électriques utilisant un courant nominal ≤75 A par phase

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IEC 60725, which is a technical report, has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. This third edition cancels and replaces the second edition, published in 2005, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- new survey and other data from countries having public supply networks operating at 60 Hz have been included;
- recommendations that were applicable to 50 Hz systems are now mirrored by new recommendations that are relevant to 60 Hz systems.

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

Enquiry draft	Report on voting
77A/784/DTR	77A/789/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 stability 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- withdrawn,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.

CONSIDERATION OF REFERENCE IMPEDANCES AND PUBLIC SUPPLY NETWORK IMPEDANCES FOR USE IN DETERMINING THE DISTURBANCE CHARACTERISTICS OF ELECTRICAL EQUIPMENT HAVING A RATED CURRENT ≤75 A PER PHASE

1 Scope

This Technical Report records the information that was available and the factors that were taken into account in arriving at the reference impedances that were incorporated in IEC 60555 and which are now incorporated in some parts of IEC 61000-3.

In addition, information is given on the impedances of public supply networks associated with service current capacities ≥100 A per phase.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤75 A and subject to conditional connection*

IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤75 A per phase*

3 Systems of low-voltage supply

3.1 Three-phase supply systems

Three-phase, four-wire, distribution systems are used worldwide to supply low-voltage consumers with nominal voltages in the region of 230 V/400 V.

To conform with IEC standard voltages, these systems are described as 230 V/400 V throughout this report.

There is considerable variation in the way in which the supplies to individual consumers are connected to three-phase systems.

In some countries, all four wires are taken into the consumer’s premises, allowing the use of three-phase 400 V for large loads, with small appliances and lighting circuits connected between one line and neutral at 230 V.

In other countries, three wires are taken into the consumer's premises, allowing the use of 400 V across two phases for large loads, with small appliances and lighting circuits connected between one line and neutral at 230 V.

In other countries, of which the United Kingdom is an example, it is unusual to take more than one phase into a residential consumer's premises. Therefore, both large loads that are less than 15 kVA and lighting circuits are supplied between line and neutral at 230 V.

3.2 Single-phase two-wire supply systems

In the rural areas of most countries, it is common to connect the winding of distribution transformers across two phases of medium voltage systems and afford supplies to low-voltage consumers via a phase and return conductor. A wide range of voltage is associated with this type of supply system.

In Korea, there are extensive networks supplying single-phase two-wire connections at 220 V.

3.3 Single-phase three-wire supply systems

In some countries, of which the United States of America is an example, a single-phase, three-wire distribution is used. Large loads are connected across the outer wires at 240 V whilst small appliances and lighting circuits are connected between one outer and the centre wire at 120 V, as shown in Figure 1.

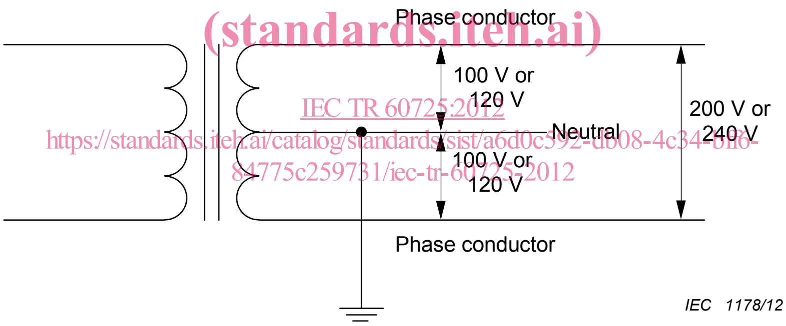

Figure 1 – Representation of a single-phase three-wire supply system

In North America, distribution systems use smaller size transformers, each supplying 4 to 8 customers with shorter secondary (LV) feeder lengths. In Japan the nominal supply voltages are 100 V and 200 V.

These supply systems have quite different supply impedances from those of three-phase distribution systems and might require a different reference impedance for testing equipment having a rated voltage within the range 100 V to 125 V.

4 Supply impedances

4.1 Typical residential premises

The supply system impedance associated with the supply to the premises of a typical residential consumer, is determined by the average value of maximum power demand of all the consumers connected to a typical network and the steady state voltage drop at maximum load used to design the system.

Information on the supply system impedance was collected from as many countries as possible and is presented in Tables 1 to 5. The impedance to be considered was the impedance up to the point of common coupling with other consumers. However, in many systems, particularly where there were several apartments in the same building, the point of common coupling was close to the metering point. Hence, the impedance figures obtained usually include both the supply system impedance and the service connection impedance.

The phase-to-neutral impedance characteristics of three-phase supply systems, in which each consumer is supplied at 230 V, 50 Hz, differ widely between countries. An international survey of residential consumers' complex supply impedances for single-phase connections at 50 Hz is shown in Table 1.

Table 1 – Residential consumers' complex supply impedances at 50 Hz

Country	Year in which data was provided to IEC	Percentage of consumers having supply impedances equal to or less than the listed complex values in Ω			
		98 %	95 %	90 %	85 %
Australia	2011	0,42 + j0,38	0,30 + j0,27	0,25 + j0,23	0,22 + j0,20
Belgium	1980	–	0,63 + j0,33	0,32 + j0,17	0,28 + j0,15
France	1980	–	0,55 + j0,34	0,45 + j0,25	0,34 + j0,21
Germany	1980		0,45 + j0,25	0,36 + j0,21	0,31 + j0,17
Ireland[a]	1980	1,47 + j0,64	1,26 + j0,60	1,03 + j0,55	0,94 + j0,43
Italy	1980	–	0,59 + j0,32	0,48 + j0,26	0,44 + j0,24
Netherlands	1980	–	0,70 + j0,25	0,41 + j0,21	0,32 + j0,17
Switzerland	1980	–	0,60 + j0,36	0,42 + j0,25	0,30 + j0,18
United Kingdom	1980	0,46 + j0,45	–	0,25 + j0,23	–
USSR	1980	–	0,63 + j0,30	0,50 + j0,26	–
NOTE This table shows the phase-to-neutral impedance for single-phase systems.					
[a] System impedances for residential consumers in Poland are similar to those in Ireland.					

Since 1981, when the impedance survey was published as Table 1, there has been natural development and reinforcement of public supply networks and the 1980 values in the 90 % column, on which the reference impedances for residential supplies were based, are now more relevant to the 95 % column because supply impedances have been reduced overall.

Information on the measurement of supply impedances is given in Annex C.

The impedance data for residential supply systems, based on study data from the year 2000 and surveys from countries with systems other than 230 V/400 V, are summarized in Tables 2 to 5.

Table 2 – Single-phase device capacities <100 A per phase

Country	Connections V	Percentage of consumers having supply impedances equal to or less than the listed complex values in Ω					Remarks
		98 %	95 %	90 %	85 %	Others	
Canada	100 to 120		0,20+j0,06			–	Survey/Calculation
	200 to 240		0,20+j0,08			–	
USA	100 to 120			0,09+j0,05			Calculation (10 % of customers have higher impedance)
	200 to 240			0,10+j0,06			
Mexico [a]	100 to 120		0,10+j0,07			–	Calculation
	127		0,16+j0,08			–	
Korea	220	0,40+j0,18	0,34+j0,15	0,31+j0,11	0,28+j0,10	–	Survey
Japan	100		0,35+j0,13			–	Survey/Calculation
	200		0,42+j0,21			–	

NOTE 1 The figures for the USA are 90th percentile.

NOTE 2 All references to data from Korea relate to data from South Korea.

NOTE 3 The data from Korea has been taken from rural and urban networks.

NOTE 4 The wide difference in network topographies in the 60 Hz countries mean that it is not possible to provide a single reference impedance 60 Hz countries.

NOTE 5 TBD (to be derived).

[a] The values for Mexico are listed under the 95 percentile but Mexico is working towards 100 % of the network impedance values to be at or below the specified values.

Table 3 – Three-phase service capacities <100 A per phase

Country	Connections V	Percentage of consumers having supply impedances equal to or less than the listed complex values in Ω				Remarks
		98 %	95 %	90 %	85 %	
Canada	120/208	TBD	0,07+j0,04	TBD	TBD	Survey/CalculationCIRED paper
USA	277/480	No data		0,10+j0,06		Estimate/survey
Mexico [a]	277/480		0,11+j0,09			
Korea	220/380	0,30+j0,20	0,29+j0,18	0,26+j0,16	0,22+j0,15	Survey
Japan	200	No data	0,38+j0,18			Survey/ Calculation estimate based on JIS-C IEC 61000-3-2

NOTE 1 The figures for the USA are 90th percentile.

NOTE 2 All references to data from Korea relate to data from South Korea.

NOTE 3 The data from Korea has been taken from rural and urban networks.

NOTE 4 The wide difference in network topographies in the 60 Hz countries mean that it is not possible to provide a single reference impedance 60 Hz countries.

NOTE 5 TBD (to be derived).

[a] The values for Mexico are listed under the 95 percentile but Mexico is working towards 100 % of the network impedance values to be at or below the specified values.

4.2 Large residential, commercial and light industrial premises

4.2.1 General

The premises considered in this subclause have service current capacities equal to or in excess of 100 A per phase.

It is anticipated that the number of requests from consumers and their agents to distribution network operators for information relating to the system impedance at their supply terminals will increase as a consequence of the publication of IEC 61000-3-11 and the procedure for the conditional connection of equipment that it promulgates.

In order to assist distribution network operating companies worldwide in determining a practical value of actual supply impedance at a particular consumers' premises and to assist manufacturers in assessing the marketability of their products in particular countries worldwide, a basic approach to the determination of maximum supply impedance has been developed and is given in Annex A.

The following values of supply impedance have been obtained by application of the method given in Annex A, on the assumptions that

a) the distribution transformer has a rating of 500 kVA, a 3 % voltage regulation or a 2,68 % reactance,
b) there is 95 % probability of occurrence, i.e. 5 % of consumers, are likely to have a supply system impedance greater than the tabled values.

If necessary, these supply impedances, or the maximum supply impedances listed in Annex A, Tables A.1 and A.2, may be amended to represent national or particular public supply networks in accordance with Clause A.5.

The impedance data for residential supply systems, based on recent studies and surveys from countries with systems other than 230 V/400 V, is summarized in Tables 4 and 5.

Table 4 – Single or two-phase service capacities ≥100 A per phase

Country	Connections V	Percentage of consumers having supply impedances equal to or less than the listed complex values in Ω				Remarks
		98 %	95 %	90 %	85 %	
Canada	347	TBD	0,58+j0,11	TBD	TBD	Survey/Calculation
USA	480	No data	No data	0,10+j0,06		Estimate/survey
Korea	220	0,32+j0,14	0,29+j0,12	0,27+j0,11	0,22+j0,09	Survey
Japan		No data	No data	No data	No data	
TBD = To be derived.						

Table 5 – Three-phase service capacities ≥100 A per phase

Country	Connections V	Percentage of consumers having supply impedances equal to or less than the listed complex values in Ω				Remarks
		98 %	95 %	90 %	85 %	
Canada	600	TBD	0,39+j0,07	TBD	TBD	Survey/Calculation CIRED paper
USA	480	No data	No data	No data	No data	
Korea	380	0,27+j0,21	0,24+j0,19	0,21+j0,17	0,20+j0,17	Survey
Japan	–	–	–	–	–	Not applicable
TBD = To be derived.						

4.2.2 Supply impedance relevant to the connection of three-phase equipment

Table 6 contains, under the assumptions stated in 4.2, the values of the modulus in ohms, of the supply impedance of the line-conductors of 230 V/400 V, 50 Hz public electricity supply networks relevant to three-phase services, the various statutory voltage ranges declared to consumers and service capacities in common use.

Table 6 – Modulus values of supply impedance, in ohms at 50 Hz, relevant to the connection of three-phase equipment and having a 95 % probability of not being exceeded

Declared voltage range %	Service capacity in amperes per phase				
	150 A	200 A	300 A	400 A	600 A
8	0,09	0,06	0,04	0,03	0,02
9	0,10	0,07	0,05	0,04	0,03
10	0,11	0,08	0,05	0,04	0,03
11	0,12	0,09	0,06	0,05	0,03
12	0,14	0,10	0,07	0,05	0,03
13	0,15	0,11	0,08	0,06	0,04
14	0,17	0,13	0,08	0,07	0,04
15	0,18	0,14	0,09	0,07	0,05
16	0,20	0,15	0,10	0,08	0,05
17	0,21	0,16	0,10	0,08	0,05
18	0,22	0,17	0,11	0,09	0,06
19	0,24	0,18	0,12	0,09	0,06
20	0,25	0,19	0,13	0,10	0,06

4.2.3 Supply impedances relevant to the connection of single-phase equipment

Table 7 contains, under the assumptions stated in 4.2, the values of the modulus, in ohms, of the supply impedance of the line-to-neutral conductors of 230 V/400 V, 50 Hz public electricity supply networks relevant to the connection of single-phase equipment to three-phase 4-wire services.

Table 7 – Modulus values of supply impedance, in ohms at 50 Hz, relevant to the connection of single-phase equipment and having a 95 % probability of not being exceeded

Declared voltage range %	Service capacity in amperes per phase				
	150 A	200 A	300 A	400 A	600 A
8	0,13	0,10	0,06	0,05	0,03
9	0,15	0,12	0,08	0,06	0,04
10	0,18	0,13	0,09	0,07	0,04
11	0,20	0,15	0,10	0,08	0,05
12	0,23	0,17	0,11	0,08	0,06
13	0,25	0,19	0,12	0,09	0,06
14	0,27	0,20	0,14	0,10	0,07
15	0,30	0,22	0,15	0,11	0,07
16	0,32	0,24	0,16	0,12	0,08
17	0,34	0,26	0,17	0,13	0,09
18	0,37	0,28	0,18	0,14	0,09
19	0,39	0,29	0,20	0,15	0,10
20	0,42	0,31	0,21	0,16	0,10

5 Reference impedances

5.1 General

Values of reference impedances appropriate to low-voltage public supply systems are given in the following subclauses; some are values already established in IEC 61000-3-3 and IEC 61000-3-11, whilst others, pertaining to 60 Hz supply systems, are recommended values.

It should be clearly understood that it is not possible to define a single reference impedance that applies in all regions of the world, because of different supply voltages and different distribution systems.

5.2 Reference impedances for equipment with current ratings ≤16 A

5.2.1 Overview

Equipment having current ratings ≤16 A is mainly connected in premises having service current capacities less than 100 A per phase. Such premises are predominantly in residential supply areas, which were initially surveyed in Europe in 1980, while other surveys have been made at more recent dates. Reference impedances relevant to the connection of equipment having current ratings ≤16 A have therefore been derived from the values given in Table 1.

It was planned that the reference impedances should represent existing system impedances and have values that can be used to assess the emissions of equipment against voltage limits with a view to ensure that connection of equipment to a public supply network would not cause undue voltage disturbance and distortion.

It has not proved possible to find an automatic and logical way of relating the reference impedance to the range of system impedances. It was recognised that to say that 10 % of consumers had supply impedances greater than a given value did not imply that 10 % of consumers would be disturbed. A consumer at the far end of a line causes less disturbance (due to voltage fluctuations or harmonic distortion) to consumers nearer to the source than to his immediate neighbour.

Divergence of views about the use of a single reference impedance may be summarized as follows:

a) some countries with high impedance networks do not consider it economically possible to reinforce their networks;

b) some countries with high impedance networks have no need to reinforce their networks because they have readily available alternative fuels for cooking and heating appliances;

c) some countries are not concerned with the switching of significant loads at 230 V because they connect large appliances to two or three phases at 400 V.

The values in the following subclauses were chosen as reference impedances and take account of experience with the use of existing appliances on existing systems as well as the survey values of system impedance presented in Tables 1, 2, 3, 4 and 5.

5.2.2 50 Hz and 60 Hz low-voltage supply systems

5.2.2.1 Three-phase, four-wire, 230 V/400 V supply systems with service capacities <100 A

Adoption of the following reference impedances, Z_{ref}, for testing purposes is recommended, see Table 8.

Table 8 – Reference impedances for testing purposes

Conductor	Impedances Ω
Phase conductor	0,24 + j0,15
Neutral conductor	0,16 + j0,10
Total	0,40 + j0,25

NOTE In Korea, there are three-phase four-wire 220 V/380 V low-voltage supply networks.

5.2.2.2 Single-phase, two-wire 230 V systems with service capacities <100 A

In this category of supply systems, Ireland has a network in which a high percentage of consumers have supply impedances greater than (0,4 + j0,25) Ω. Italy and Poland also have a large proportion of rural networks with relatively high supply impedances. In the United Kingdom, supplies to only about 2 % of consumers exceed (0,4 + j0,25) Ω.

A single value of reference impedance of (0,4 + j0,25) Ω (phase to neutral) has been adopted with the advantages that

- this value gives the same limit conditions for appliances manufactured for use in all countries;
- it complies with the decision that there should be a single reference impedance used for the assessment of emissions from equipment rated ≤16 A per phase;
- it simplifies the test house procedure;
- experience shows that most appliances already connected to public supply systems comply with limits based on this impedance (but there are exceptions);
- it simplifies the setting of limits.

The choice of a single impedance also has disadvantages, namely:

- although conditions on networks with relatively high impedance are normally acceptable at present, this may not be so if equipment intended for simultaneous use in large numbers were designed to produce the maximum values of voltage change foreseen;