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Considerations on reference impedances for use in determining the disturbance characteristics of household appliances and similar electrical equipment

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CONSIDERATIONS ON REFERENCE IMPEDANCES FOR USE IN DETERMINING THE DISTURBANCE CHARACTERISTICS OF HOUSEHOLD APPLIANCES AND SIMILAR ELECTRICAL EQUIPMENT

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This report has been prepared by IEC Technical Committee No. 77: Electromagnetic Compatibility Between Electrical Equipment Including Networks.

A first draft was discussed at the meeting held in The Hague in 1979. As a result of this meeting, a draft, Document 77(Central Office)6, was submitted to the National Committees for approval under the Six Months' Rule in June 1980.

The National Committees of the following countries voted explicitly in favour of publication:

Australia
Belgium
Egypt
France
Germany
Hungary
Ireland
Italy
Japan
Netherlands
New Zealand
Norway
Poland
South Africa (Republic of)
Sweden
Switzerland
Turkey
Union of Soviet Socialist Republics
United Kingdom
United States of America
Yugoslavia

Other IEC publication quoted in this report:

Publication No. 555: Disturbances in Supply Systems Caused by Household Appliances and Similar Electrical Equipment.

555-3: Part 3: Voltage Fluctuations (being printed).

CONSIDERATIONS ON REFERENCE IMPEDANCES FOR USE IN DETERMINING THE DISTURBANCE CHARACTERISTICS OF HOUSEHOLD APPLIANCES AND SIMILAR ELECTRICAL EQUIPMENT

1. Object

This report records the information that was available and the factors that were taken into account in arriving at the reference impedances that have been incorporated in IEC Publication 555: Disturbances in Supply Systems Caused by Household Appliances and Similar Electrical Equipment.

2. Systems of supply

Three-phase, four-wire, distribution systems are widely used for household consumers, with nominal voltages of 220/380 V, 230/400 V and 240/415 V.

To conform with IEC standard voltages, this system is described as 230/400 V throughout this report.

There is considerable variation in the way in which individual household consumers are connected to the 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 heavy 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 heavy 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 domestic consumer's premises. Consequently both heavy loads and lighting circuits are supplied between line and neutral at 230 V.

In some countries, of which the United States of America and the Netherlands are examples, a single-phase, three-wire distribution is used. Heavy loads are connected across the outers at 230 V whilst small appliances and lighting circuits are connected between one outer and the centre wire at 115 V. This leads to quite different supply impedances from those of three-phase distribution systems and may require different reference impedances.

A reference impedance appropriate to single-phase three-wire distribution systems has not been recommended and this subject is to receive further study.

It was found that three-phase supplies at 127/220 V and similar systems are of small and decreasing importance. No reference impedance has been recommended for these supplies.

3. System impedances

The supply system impedance is determined by the values of average maximum power demand of the consumers and steady voltage drop at maximum load used to design the system.

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

The impedance characteristics of systems in which each consumer is supplied at 230 V differ widely between countries as shown in the following table:

TABLE I

System impedance in ohms at 50 Hz

Country	Percentage of consumers with less than stated impedance			
	98%	95%	90%	85%
Australia	–	0.43 + j 0.33	–	–
Belgium	–	0.63 + j 0.33	0.32 + j 0.17	0.28 + j 0.15
France	–	0.55 + j 0.34	0.45 + j 0.25	0.34 + j 0.21
Germany	–	0.45 + j 0.25	0.36 + j 0.21	0.31 + j 0.17
Ireland*	1.47 + j 0.64	1.26 + j 0.60	1.03 + j 0.55	0.94 + j 0.43
Italy	–	0.59 + j 0.32	0.48 + j 0.26	0.44 + j 0.24
Netherlands	–	0.70 + j 0.25	0.41 + j 0.21	0.32 + j 0.17
Switzerland	–	0.60 + j 0.36	0.42 + j 0.25	0.30 + j 0.18
United Kingdom	0.46 + j 0.45		0.25 + j 0.23	–
Union of Soviet Socialist Republics	–	0.63 + j 0.30	0.50 + j 0.26	–

* System impedances for household consumers in Poland are similar to those in Ireland.

4. Reference impedances

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 recognized that a statement that, say, 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 would cause less disturbance (by voltage fluctuation 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:

1) The United Kingdom has a low impedance network, and is not prepared to degrade the performance of existing acceptable high power appliances used in large quantities.

2) Some countries with high impedance networks do not consider it economically possible to reinforce their networks.

3) 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.

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

The values chosen as recommended reference impedances took account of experience with the use of existing appliances on existing systems as well as survey values of system impedance.

4.1 *Three-phase, four-wire, 230/400 V supplies*

Adoption of the following reference impedances is recommended:

Phase conductor	0.24 + j 0.15 Ω
Neutral conductor	0.16 + j 0.10 Ω
Phase to neutral impedance	0.40 + j 0.25 Ω

4.2 *Single-phase, two-wire, 230 V supplies*

In this category Ireland has a network in which 40% of consumers have a supply impedance greater than 0.4 + j 0.25 Ω. Italy and Poland also have a large proportion of rural network with relatively high supply impedance. In the United Kingdom, supplies to only about 2% of consumers exceed 0.4 + j 0.25 Ω. Application of the curve of Figure 4 in IEC Publication 555-3: Part 3: Voltage Fluctuations (being printed), would limit the power of a heating element switched five times per minute to about 2 kW. Some cookers at present used in the United Kingdom have grill elements of 2.75 kW and would exceed this limit. United Kingdom manufacturers do not wish to change their practice which is quite suitable for the low impedance United Kingdom network.

A suggestion that different reference impedances should be specified for appliances intended for use on different networks was unacceptable. After a great deal of discussion it was decided to recommend a single value of reference impedance of 0.4 + j 0.25 Ω (phase to neutral) at 50 Hz. Among the advantages of having a single reference impedance are the following:

a) this value gives the same limit conditions for appliances manufactured for use in all countries;

b) it complies with the decision that there should be a single reference impedance, at least up to 3 kVA;

c) it simplifies test house procedure;

d) experience shows that most appliances already used in supply systems comply with limits based on this impedance (but there are exceptions);

e) it simplifies the setting of harmonic limits.

The choice of a single impedance also has disadvantages namely:

a) 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;

b) equipment which forms part of a larger appliance and operates for only short periods and which is known to be acceptable, would be prohibited.

It was decided to add a statement to IEC Publication 555-3, dealing with voltage fluctuations, to the effect that consent by the supply authority is appropriate for high power appliances which are intended only to be used in systems having impedances considerably lower than the reference impedance.

4.3 *Single-phase, three-wire, 120/240 V supplies*

Reference impedances for these supplies were proposed. However, it was later realized that these values would result in appliances designed with a rated voltage close to 230 V in different countries having to meet different disturbance characteristics. This could present problems for international trade. When this difficulty was discovered, there was insufficient time to obtain a considered response from the experts in the United States of America and Japan to a proposal that the reference impedance of 0.4 + j 0.3 Ω (phase to neutral at 60 Hz) should apply to all 230 V appliances irrespective of the network. Therefore, no recommendation is made in this report.

5. Harmonic impedance

Although theoretical considerations suggest that resonance between power factor correction capacitors (e.g. in fluorescent luminaires) and the system inductance is possible at harmonic frequencies, the only measurements available do not show this phenomenon. For this reason, it is recommended that the reference impedance be regarded as purely resistive and inductive for assessing harmonics.