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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Power transformers – Part 25: Neutral grounding resistors

Transformateurs de puissance – Partie 25: Résistances de mise à la terre du neutre

IEC 60076-25:2023-02(en-fr)

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Part 25: Neutral grounding resistors

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Partie 25: Résistances de mise à la terre du neutre

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POWER TRANSFORMERS –

Part 25: Neutral grounding resistors

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The text of this International Standard is based on the following documents:

Draft	Report on voting
14/1097/FDIS	14/1101/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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A list of all parts in the IEC 60076 series, published under the general title *Power transformers*, can be found on the IEC website.

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POWER TRANSFORMERS –

Part 25: Neutral grounding resistors

1 Scope

This part of IEC 60076 applies to dry type natural air-cooled resistors, for neutral grounding of transformers and generators, in order to limit the earth fault current in power systems by means of metallic resistive elements.

For the purposes of this document, the resistor can be:

- used alone or in combination with other electrotechnical products not covered by this document, such as (but not limited to): a step-down single-phase transformer, an open triangle or zig-zag transformer (where the neutral point is not available) and a Petersen coil reactor (in order to increase active power contribution to the fault or reduce time constant for proper protection operation or both);
- designed, manufactured and verified on a one-off basis or fully standardized and manufactured in quantity.

Both terms "neutral grounding resistor" (NGR) and "neutral earthing resistor" (NER) can be used. However, for the purposes of this document and in order to avoid any confusion with "neutral earthing reactor" (NER), the term "neutral grounding resistor" (NGR) is used.

This document specifies:

- the characteristics of the NGR;
- the service conditions requirements for NGRs;
- the tests and test methods for confirming that these conditions have been met;
- the requirements relating to marking for NGRs.

Annex A provides guidance on how to consider the effect of resistance variation with temperature.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1:2010, *High voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-2, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60076-3:2013, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*
IEC 60076-3:2013/AMD1:2018

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529/AMD1:1999
IEC 60529/AMD2:2013

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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

IEC and ISO maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
NGR
neutral grounding resistor
neutral grounding device where the principal element is resistance

3.2
resistive element
unitary current carrying conductor, usually in the form of grids, plates, strips, ribbons or wires and which can have intermediate tapings

3.3
resistive bank
sub-assembly consisting of one or multiple resistive elements supported by the same structure

Note 1 to entry: One or multiple resistive banks form a complete NGR.

3.4
IN terminal
higher voltage terminal of the NGR, connected to the grounded equipment's neutral terminal

3.5
OUT terminal
lower voltage terminal of the NGR, connected to earth

3.6
rated short time current
I_{str}
value of the initial RMS current upon the application of the rated voltage

3.7
continuous current
I_r
steady state RMS value of current

3.8
extended time
period of time that is greater than the time required for the temperature rise to become constant but limited to 90 days of operation per year

3.9
highest voltage for equipment
U_m
highest RMS phase to neutral voltage for which the NGR is designed in respect of its insulation

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3.10
power frequency withstand voltage
U_d
RMS value of sinusoidal power frequency voltage that the insulation of the NGR can withstand during tests made under specified conditions and for a specified duration

3.11
impulse withstand voltage
U_p
highest peak value of impulse voltage of specified form and polarity which does not cause breakdown of insulation under specified conditions

3.12
protective earthing terminal
terminal connecting the NGR's enclosure to earth for protective purposes

3.13
working voltage
U_w
highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

3.14
temperature coefficient of resistance
parameter describing the change in resistance relative to a given change in temperature

Note 1 to entry: The temperature coefficient of resistance is expressed by:

$$\alpha = \frac{R_2 - R_1}{R_1(\theta_2 - \theta_1)} \quad (1)$$

where

R_1 and R_2 are resistances, in Ω, at temperatures θ_1 and θ_2, in °C, respectively, and

α is the temperature coefficient of resistance, expressed in K^{-1}, for the temperature variation between θ_2 and θ_1.

3.15
uniform insulation
insulation of an NGR where all the active material have the same insulation level towards the enclosure

3.16
non-uniform insulation
insulation level throughout the NGR construction that is graded based on the rated voltage at each part of the construction i.e. connections, banks and elements and where the OUT terminal is intended for direct connection to earth

3.17
duty cycle
specified sequence of ratings, each of them having a different combination of rated time and rated current or voltage

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4 Service conditions

Unless otherwise specified, NGRs conforming to this document are intended for use under the normal service conditions described in IEC 60076-1.

For installations at an altitude higher than 1 000 m, the required insulation level shall be corrected using the correction factor provided in IEC 60071-2.

5 Ratings

5.1 Rated ambient temperature

Unless otherwise specified, the rated ambient temperature shall be 20 °C.

5.2 Rated resistance (R)

The rated resistance is the specified resistance between the IN terminal and OUT terminal at the rated ambient temperature.

Unless otherwise stated, the tolerance of the rated resistance value is ±10 %.

5.3 Maximum resistance variation

The purchaser shall also specify the maximum allowable variation of resistance at the maximum temperature rise in per cent of rated resistance.

NOTE Certain applications such as high impedance grounding or sensitive networks can require a maximum variation as low as 10 % whereas others can accept a variation as high as 100 %. See Annex A for guidance.

5.4 Rated time

The rated time is the time the NGR shall withstand the rated voltage and the specified combination of rated short time current and rated continuous current.

The rated time shall be specified by the purchaser.

Typical rated times are 3 s, 5 s,10 s, 30 s and 60 s, extended time or continuous.

If a duty cycle is to be considered it shall be detailed in the technical specification.

5.5 Rated voltage (U_r)

When the NGR is connected directly between the neutral point and the earth the rated voltage across the NGR is the phase to neutral voltage and is equal to the nominal system voltage for which the equipment is designed, divided by the square root of three.

$$U_r = \frac{U}{\sqrt{3}} \tag{2}$$

In some specific cases, the rated voltage can be different, for example, for resistors installed on the low voltage side of a step-down transformer or for resistors installed in series or parallel to a neutral earthing reactor.

In the case of combined equipment, for example neutral grounding resistors and zig zag transformers, IEC 62271-1 applies.

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NOTE Standard values of system voltages (U) are given in IEC 60071-1 for system voltages above 1 000 V and in IEC 60664-1 for system voltages below 1 000 V.

5.6 Rated insulation level

The rated voltage U_r as defined in 5.5 shall be the basis to determine the rated insulation level and clearance distances in air in Table 1 chosen as the next standard value of U_m equal to or higher than U_r.

Table 1 – Rated insulation levels

Highest voltage for equipment U_m kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)	Rated lightning impulse withstand voltage U_p kV (peak value)	Minimum air clearance mm (IEC 60076-3:2013, Table 4), except for U_m = 1kV
1,0	2,2	12	14
3,6	10	40	60
7,2	20	60	90
12	28	75	120
17,5	38	95	160
24	50	125	220
36	70	170	320
52	95	250	480
72,5	140	325	630
100	185	450	900
123	230	550	1 100
145	275	650	1 300
170	325	750	1 500
245	460	1 050	2 100

Other rated insulation levels according to national standards may be used if specified by the purchaser.

5.7 Rated short time current

The rated short time current shall be specified by the purchaser.

5.8 Rated continuous current

The rated continuous current shall be specified by the purchaser.

NOTE The rated continuous current, usually due to imbalances, is an additional rating to a resistor that has a rated time duty that is not continuous.

5.9 Rated frequency

The rated frequency shall be the system's frequency.

NOTE The standard values of the rated frequency are 50 Hz and 60 Hz.

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6 Rating plates (Nameplates)

6.1 General

The NGR shall be provided with a rating plate, fitted in a visible position. It shall be fabricated with weatherproof materials and be able to withstand the NGR's enclosure temperature. The entries on the plate shall be indelibly marked (for example by etching, engraving or stamping).

6.2 Minimum information to be provided

a) manufacturer's name;

b) manufacturing location;

c) year of manufacture;

d) type designation or identification number or any other means of identification, making it possible to obtain relevant information from the manufacturer;

e) number of this standard;

f) rated resistance (R) at ambient temperature;

g) maximum temperature rise;

h) maximum change in resistance (%);

i) ambient temperature;

j) rated voltage (U_r);

k) highest voltage for equipment (U_m);

l) rated power frequency voltage (U_d);

m) rated impulse withstand voltage (U_p);

n) rated short time current (I_{str});

o) rated continuous current (I_r);

p) rated frequency (f_r);

q) rated time (T);

r) total mass;

s) degree of protection.

7 Design and construction

7.1 General

The design and construction of the NGR shall consider the dielectric, thermal and mechanical effects of its operation and the environmental conditions.

7.2 Resistive elements

The design and materials of resistive elements shall withstand the NGR's operating temperature range, successive heating-cooling cycles and environmental stresses. The maximum temperature rises are given in Table 2.

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Table 2 – Maximum temperature rises above ambient for resistive elements

Rated time	Maximum temperature rise K
Equal or less than 60 s	760
Extended time and less than 10 min	610
Continuous	385

The temperature rise is the difference between the temperature of the resistive elements at the end of the rated time and the ambient temperature.

NOTE The temperature rise limits given in Table 2 are absolute maximum values, the maximum applicable temperature rise can be lower depending on the resistive element design.

7.3 Resistive banks

Resistive banks shall have a design capable of withstanding the mechanical and thermal stresses likely to be encountered during operation.

Appropriate measures shall be taken as to preserve the electrical insulation between elements and between live parts and support structures and enclosures.

Insulation coordination shall be maintained under the effect of thermal expansion.

7.4 Electrical connections

The connections between resistive elements within the resistive banks shall be appropriate to ensure adequate current carrying capacity at all operating temperatures.

The connections between resistive elements of different banks and between elements and the IN and OUT terminals shall have designs capable of withstanding the thermal and mechanical stresses likely to be encountered within the enclosure.

7.5 IN and OUT terminals

7.5.1 General

The IN and OUT terminals shall be clearly marked and identified.

Insulation materials of wall bushings shall withstand the mechanical and thermal stresses likely to be encountered during operation.

7.5.2 IN terminal

The IN terminal shall be rated to the NGR's rated insulation level.

7.5.3 OUT terminal

The OUT terminal shall be insulated from the enclosure and from protective earthing terminal.

Unless otherwise specified the NGR shall have an OUT terminal insulated from the enclosure by a minimum U_m rating of 1 kV (according to Table 1).

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7.6 Insulators

7.6.1 General

Insulators shall be able to withstand the mechanical and thermal stresses likely to be encountered during operation.

7.6.2 Insulators between resistive elements

Insulators between adjacent resistive elements and between resistive elements and any other part that are in direct contact with the element's surface shall be fabricated with materials capable of withstanding the NGR's operating temperature range and successive heating-cooling cycles.

7.6.3 Insulators between resistor banks and enclosure

Insulators between resistor banks and enclosure shall be coordinated with the NGR's rated insulation level.

7.6.4 Creepage distance

If a specific creepage distance is specified, the creepage distance calculation shall be based on the working voltage U_{W}.

NOTE 1 It is common practice to consider the internal insulation of an NGR whose enclosure has a degree of protection of IP23 or higher as indoor insulation.

NOTE 2 Considering that the insulators are not subject to the same environment load as the outdoor ones, it is common practice to have a lower creepage distance in indoor insulation.

7.7 Enclosure

7.7.1 Protection against contact with live parts, ingress of solid foreign bodies and water

The degree of protection provided by the NGR's enclosure against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529 and verified according to 8.6.4.

The NGR's enclosure shall be suitably ventilated to dissipate the heat generated during operation.

NOTE The degree of protection IP 23 is considered as an optimum compromise between protection and ventilation for outdoor installation for most environments.

7.7.2 Design

7.7.2.1 Warning labels

Appropriate warning labels shall be installed, for example "HOT SURFACE" and "HIGH VOLTAGE" where they are visible and legible when the NGR is installed and operating. They shall be fabricated with weatherproof materials and be able to withstand the NGR's enclosure temperature.

7.7.2.2 Handling and lifting

The NGR's enclosure shall be provided with means to facilitate handling and lifting without compromising its designed voltage withstand capabilities or its degree of protection.

If the NGR's mass is above 25 kg, provision shall be made for mechanical lifting.

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