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A guide to specifying neutral earthing resistors (NERs)

Voltage
Neutral earthing resistors or NERs are often described by the system voltage of the supply, eg an “11kV NER”.

The maximum voltage that the resistor actually experiences in service is the line voltage (phase to neutral voltage). Hence the rating plate of the resistor will bear the line voltage. Eg an “11kV NER” is rated at 6.35kV.

Current
Resistors are rated by current at line voltage. System impedances are usually ignored. This implicitly specifies the resistance value. There is usually a 10% tolerance on the current value.

Choice of current rating depends on the characteristics of the system and equipment. For example, a generator manufacturer may specify a tolerable maximum value of earth fault current. Choice also depends on the type of protection relay system employed. Older systems need higher currents to operate. Newer systems can have the sophistication to operate reliably at lower currents. In the absence of specific information, the current is usually chosen to be equal to or lower than the rated current of the transformer or generator. Current values generally lie between tens of amps and thousands of amps.

Time
Resistors are generally rated to carry their current for a time of 10 seconds. The current will actually flow for a much shorter time than this. The 10 second time is chosen to allow for the occurrence of multiple events. This can happen when auto-reclosers are used. It also allows for the operation of an upstream backup protection device if the protection relay fails.

Time of 30 seconds usually indicates an old specification based on liquid resistors. The long duration reflects the extended cooling time associated with this old technology.

Continuous current
NERs are generally rated for occasional use and unless specified have a limited capacity to handle a continuous current, if a continuous current is required this will pre-heat the resistor and reduce the allowable element temperature rise related to the short time (fault) duty, this means that a requirement for a continuous current could result in a larger and more expensive resistor. For this reason, unless specified, we will not usually include for a continuous current rating in a design of the NER.

When a continuous current is required, this will typically be between 2.5 and 10% of the short time (fault) rating, it is important to consider both the value of current and the power associated with it – the higher the power the greater the impact on the resistor design.

If a continuous current is specified the resistor must be designed to dissipate the associated power, an enclosure specified with limited ventilation (such as IP54 or 55) will restrict cooling by convection, this will lead to extended cooling times and potentially higher enclosure surface temperatures as the majority of the cooling will occur through radiation from the enclosure surfaces, for this reason when a continuous current rating is requested we will usually recommend an IP23 or 33 enclosure.

Insulation levels
NERs never experience voltages in excess of line voltage. Insulation levels should therefore be specified based on line voltage. Despite this, some specifiers choose to specify insulation based on system voltage. This has a significant impact on the size, weight and cost of the NERs designed for higher voltage levels.

Temperature rise
Temperature rise is limited to 760°C maximum, in accordance with IEC 60076-25 (2023) or IEEE-C57.32a (2020). Most of the resistance alloys used have the capability to operate at temperatures above this, potentially up to 1000°C without problem.

Applicable standards
For many years resistors were designed in line with IEEE-32, 1972 (except where current IEC standards could be applied such as insulation and IP requirements). IEEE-32 was revised and republished in December 2015 under the reference C57.32, this introduced a change relating to temperature coefficient of resistance (TCR) see below, this change resulted in significant increases to both the size and price of many resistor designs and so it was subsequently revised in August 2020.
The current version of the standard is IEEE-C57-32a (2020).

In February 2023 IEC issued a European standard for resistors, IEC 60076-25, we can offer to either standard.

Temperature coefficient of resistance (TCR)
Metallic resistors have a positive temperature coefficient of resistance (TCR). This means that the current will not exceed the rated value.

As metal resistors heat up their resistance value will increase, the amount of the increase will depend on the alloys used and the element temperature rise, the temperature coefficients of the alloys used can range from 0.001 to 0.148% per degree C. A lower resistance change allows more current to flow increasing the energy to be absorbed, resulting in a design that is potentially larger and more expensive than one using an alternative material with a higher resistance change.

IEC 60076-25 (2023): does not specify a resistance change with temperature however there is an advisory comment in the standard that says the maximum value of resistance change should be selected based on the network and protection systems.

The original IEEE-32 standard did not specify a resistance change, however the more recent IEEE C57-32a states the resistance change of an NER should not exceed 67%. This is to ensure that the final fault current is sufficiently high to allow protective circuitry to operate as intended.

Protection relays are typically set between 20 to 50% of the specified fault current, they will normally operate within a few seconds of an earth fault, which may be why resistance change with temperature was not originally considered.

Unless specified will usually offer the most cost-effective alloy for the specified rating.
If a material with a low coefficient of resistance is required, please let us know and we can advise you accordingly.

Element type
Metallic resistors are generally specified in preference to liquid types for a number of reasons. Metallic resistors do not suffer from evaporation, freezing, leakage and positive TCR. Metallic resistors contain no electrolyte and require minimal maintenance. Metallic resistors do not need ancillary supplies to power frost protection heaters.

It is desirable to minimise the number of joints and connections within the resistor.

It is desirable to avoid thermal hot spots within resistor elements.

It is desirable to have a homogenous voltage distribution within a resistor element.

All these requirements can be met by the use of **oval edge wound metallic coils** or **coiled coils**.

The term grid is often used in connection with high power resistor elements. Historically the term referred to an element constructed from cast iron. This type of construction has largely been superseded. The term is now generally taken to mean a heavy-duty metallic element and differentiates it from a liquid resistor.

Termination
NERs have three main terminals or connection points. The first terminal connects one end of the resistor to the neutral of the transformer or generator. The second terminal connects the remaining end of the resistor to earth. The third terminal provides enclosure earth bonding.

The enclosure earth terminal and resistor earth terminal should be separate to facilitate easy testing on site.

The resistor neutral terminal is typically in the form of a bushing rated for either the line or the system voltage.

The resistor earth terminal is typically in the form of a bushing rated for 1kV.

The enclosure earth terminal is usually in the form of a M12 stud. A second enclosure earth terminal is diagonally opposite to the first for ease of bonding.

Ingress Protection (IP) rating
NERs are typically specified to have an IP rating of IP23.

The materials used within a NER may include speciality resistive alloys, stainless steels, ceramics, galvanised steel and copper. All of these materials are durable in harsh environments. Hence the need for environment protection is low.

Where necessary, higher IP ratings can be specified. NER housings with an IP rating in excess of IP54 can significantly restrict the escape of heat from the resistor. This becomes especially important for NERs with high continuous current ratings. Such requirements can significantly increase size, weight and cost of the NER.

Specific parts of a NER such as the cable box may be specified to have a higher IP rating than the rest of the NER in order to protect equipment within. IP54 is the level of protection normally specified.

It should be noted that IP ratings only refer to ingress of water and dust in the context of NERs. NERs are high voltage electrical system components and may have exposed live parts such as bushing stems etc. NERs are hot during and after operation. The IP rating does not infer that it is safe to touch NERs.

Enclosure
Aluminised zinc treated mild steel enclosures may be specified and are suitable for most environments.

AISI 304 stainless mild steel enclosures may be specified and are more durable than aluminised zinc treated mild steel enclosures.

AISI 316L stainless steel enclosures may be specified for coastal, marine and offshore environments.

Painted pre-galvanised mild steel enclosures may be specified for indoor and moderate outdoor environments.

Painted enclosures can also be specified but are generally not desirable due to the increased maintenance requirements and the possibility of discoloration following operation of the NER.

Safety
NERs are hot during and after operation.

NERs are high voltage electrical system components and may have exposed live parts such as bushing stems etc.

Site layout, NER labelling, operation and maintenance procedures should fully take account of these hazards.

Ancillary items
Items such as vacuum contactors, switchgear, current transformers, interlocks and neutral earthing transformers may be packaged as part of the NER.