Neutral Earthing / Grounding RESISTORS

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Earthing

When designing an industrial High Voltage Network, a suitable **Neutral to Earth** arrangement must be selected: The Neutral can be either **insulated** or **connected to earth.**

- HV networks with **insulated neutral** contributes to operational continuity since it does not trip on first fault. However, Network capacitance must be such that an earth fault current will not endanger personnel or damage equipments.
- HV networks **connected to earth** do have to compromise between :
  - Damping of Over-Voltages
  - Limitation of damages and disturbances caused by an earth fault
  - Provision of a simple but selective Protecting Device

Earthing can be of different types :

- **Direct** or **Solid** Earthing
- Current **Limitation**

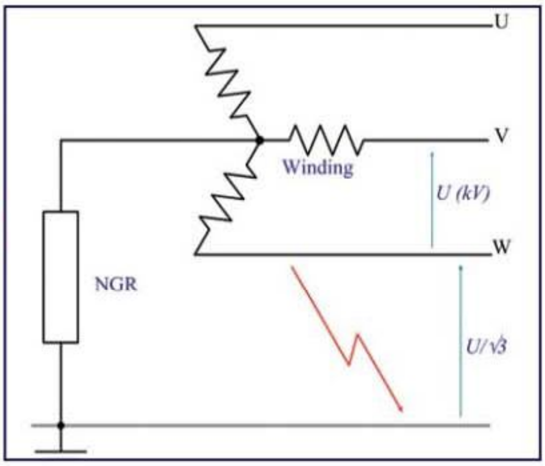
Direct or Solidly Earthing

This is the **most efficient grounding method** to limit the over-voltage. However, the current is not limited in the event of a ground fault. Damages & Interferences occur and flash hazard are important during the fault.
This method is not used for High Voltage Distribution

Current Limiting (Impedance Earthing)

Impedance Earthing **limits fault damages**, **eliminates transient over-voltages** & **reduces Flash Hazard**. It provides **adequate tripping** levels for **selective ground fault detection & coordination.**

Impedance Earthing consists in connecting a **Neutral Earthing Resistor** or **Reactor** between the **Transformer / Generator Neutral & Earth**. In the event of a Phase-to-Earth fault, the current will **flow through** the impedance and thus will be **limited.**



$$V = U/\sqrt{3} \Rightarrow I_{(f)} = V/R$$

Earthing through Reactor

- **Tuned Reactor** : This solution is sometimes used for public HV networks. Protective relays sensitive to the active component of the residual current must be used to obtain selectivity.
- **Current Limiting Reactor** : This solution can result in over voltages. It can be used only where there are low limiting impedances.

Earthing through Resistors.

This is often the most satisfactory solution. There are two grounding possibilities with Resistors.

HIGH RESISTANCE & LOW RESISTANCE GROUNDING
They are selected depending on Current Ground Fault and Fault Detection

Application Considerations

Earthing Resistance Systems are recommended for **Medium & High Voltages**.

Earthing Resistance Systems are **linked to protective relays** which will trip the circuit (if a ground to phase fault occurs) in **less than 3 sec**. However a **10 seconds or 1 (one) minute rating** is usually specified to keep extra margin even though the cost of such a system increases.

Extend Time Rating is used when it is necessary to leave a **partial ground-to-phase fault** persist for some time. The Earthing System is then dimensioned to limit the fault current but **does not shut down** the system whenever a fault occurs. The Ground Fault is then indicated and recorded by mean of light, alarm annunciation…but **the fault will not be cleared until a shutdown is scheduled.**

Data Requirements

▶ **System Voltage** : This is the Phase-to-Phase Voltage.

▶ **Rated Voltage** : This is the Phase-to-Neutral Voltage. (equal to System Voltage / √3)

▶ **Rated Fault Current** : This is the maximum Current allowed to appear in case of Fault

We always take into consideration a 1 to 3% (of rated fault current) leakage current in our design to allow unbalanced systems.

- In High Resistance Grounding, the fault current is usually limited & reduced to 25 A. They are mainly used in Distribution systems
- Low Resistance Grounding is commonly used in Transmission Systems.

▶ **Rated Fault Duration** : As per IEEE32 Std, Time Rating for the NGR is usually of **10 sec, 1 or 10 min.**

The time rating indicates the maximum time the Resistor will operate under fault condition without damage & without exceeding the **allowed Temperature Rise** above ambient temperature.

Temperature Rises allowed for Stainless Steel Resistors are

- for Rated Time lower than 10 minutes: 760°K
- for Rated Time lower than 30 minutes: 610 °K
- for SteadyState (Continuous Rating): 385°K

Adiabatic Heating

When Current flows through a Resistance for a short time, dissipation is negligible. Thus the Temperature Rise of that Resistances will depend on its **capacity to store the electrical energy** via its mass and specific heat. The rise in the resistor's temperature will be provided by the relation :

$$\Delta\theta = \int_0^T \frac{R.I^2}{m.C}.dt = \int_0^T \frac{V^2}{R.m.C}.dt$$

...where:

- *V is the Rated Voltage (Constant Value)*
- *R is the Ohmic Value (Function of the temperature)*
- *I is the Rated Fault Current (Function of the Ohmic Value)*
- *T is the Rated Fault Duration*
- *C is the specific heat of material used to make R(Function of Temperature)*
- *m is the active mass of material used to make R*

Resistance Value Calculation

The resistance varies with temperature. It can be calculated from the Resistivity Curve.

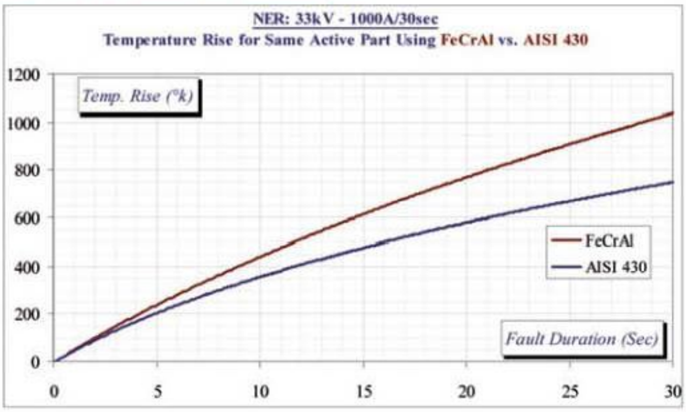
$$R2= R1x\,[1 + \alpha.(\Delta\theta)]$$

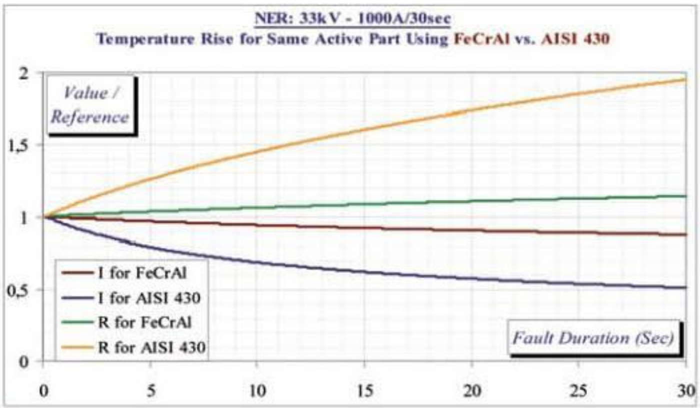
Where R2is the Ohmic Value at θ2~ R1is the Ohmic Value at θ1
α is the Temperature Coefficient –Δθis the Temperature Rise (equivalent to θ2–θ1)

Resistance Material Selection

From the various formulae above, we can understand that the higher the Temperature Coefficient α will be, the higher the Ohmic Value R at end of fault will be and thus the lower the ending Fault Current I will be. As the absorbed Energy within the Resistor is a factor of R and of I^2, it is obvious that the best solution to get a well designed Resistor is to use **an alloy that has the highest possible Temperature Coefficient**. As an example, see below resulting curves from two Resistors having the same electrical data, same mass...

Only Used alloy is changed.





NER Request Form

Electrical Data

1	System Voltage	U (kV)	
2	System Frequency	(Hz)	
3	Rated Fault Current	I_f(A)	
4	Rated Fault Duration	T_f(Sec)	
5	Leakage Current (continuous)	I_c(A)	
6	Temporary Current / Duration	(A) / (Sec)	
7	Insulation Level (Based on Rated Voltage as per IEEE-32)	(kV)	

Enclosure Arrangement / Design

8	Ambient Temperature	c°	
9	Max allowed Temperature Rise (if Different from IEEE-32)	k°	
10	Protection Level (IP Level)		
11	Housing Finishing (Galvanized, Hot Dip, Stainless Steel, painted...)		
12	"IN" Terminal Details On Top / On Side / At the Bottom Free in Air / Inside the Resistor Cubicle / In separate Enclosure		
13	"OUT" Terminal Details On Top / On Side / At the Bottom Free in Air / Inside the Resistor Cubicle / In separate Enclosure		

Accessories

14	Current Transformers (Neutral or Earthing Side -Ratio –Burden -...)	
15	Voltage Transformers (Ratio –Burden -...)	
16	Disconnectors (Current Rating –Manual / Motorized –On/Off-Load...)	
17	Surge Arrestor (Ratings ...)	

Other Comments

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