

SPECIFICATION No SS-40/9
OUTDOOR METALLIC RESISTORS FOR GROUNDING (EARTHING)
THE NEUTRAL OF 150/20KV TRANSFORMERS

I. SCOPE

This hereby specification covers IPTO's requirements with regard the design features, rated characteristics and testing of metallic grounding (earthing) resistors.

II. KEYWORDS

Grounding resistor, earthing resistor, neutral grounding devices, metallic resistors.

III. STANDARDS

The grounding resistors and their enclosures shall conform to the following standards:

1. IEEE Std C57.32a™-2020 (Amendment1 του IEEE Std C57.32-2015)
“Requirements, Technology and test procedure for neutral
grounding devices”
2. IEC-60529 “Degree of protection provided by enclosures”
3. IEC-60137 “Insulated bushings for alternating voltages above 1000V”
4. IEC-60273 “Characteristics for indoor and outdoor post insulators for
systems with nominal voltages greater than 1000V”

IV. USE

The resistors are to be used in connection with the neutral of 150/20KV transformers to earth (ground) the neutral and thus to limit the earth fault current to 1000A. The 150/20KV transformers are of delta-star (wye) earthed connection. Under normal conditions, the 20KV neutral has practically the potential of the earth (ground). However, a residual current of some amperes may flow permanently through the resistor due to small phase unbalance loading of the distribution lines and harmonics. It should also be stated that in case of faults through very large resistance, more significant currents may flow through the resistor for relatively long periods. In the event of a bolt (practically no resistance being involved) phase to earth fault, a large current will flow and the resistor will be exposed to a voltage which equals approximately to the phase to neutral voltage of the system ($21KV/\sqrt{3}=12KV$). This large current will be cleared by the protection system of the substation.

v. SERVICE CONDITIONS

- | | |
|------------------------------|--------------------------------|
| 1. Installation | : Outdoors inside an enclosure |
| 2. Ambient temperature range | : - 25°C to +45°C |
| 3. Altitude | : Up to 1000m above sea level |
| 4. Relative humidity | : ≤ 95% |
| 5. Pollution level | : moderate |
| 6. Other weather conditions | : Snow, ice and fog |

VI. 20KV SYSTEM CHARACTERISTICS

- | | |
|---|--------------|
| 1. Rated Voltage | : 20KV |
| 2. Maximum Voltage | : 24KV |
| 3. Rated frequency | : 50Hz |
| 4. Short circuit level | : 10KA |
| 5. Number of phases and conductors | : 3 |
| 6. Lightning impulse withstand voltage (BIL) for equipment in enclosures only | : 125KV peak |
| 7. Power frequency withstand voltage (for equipment in enclosures only) | : 50KV rms |

VII. DESIGN FEATURES OF THE RESISTOR AND ITS ENCLOSURE (HOUSING)

1. The resistors shall be self-cooled of the outdoor type inside a metallic enclosure.
2. The material of the resistors (conductive part) shall be of metal or metal alloy with appropriate anticorrosive plating, if the metal or the metal alloy is susceptible to corrosion.
3. The resistors shall be supplied inside a metallic enclosure (housing).
4. The metallic enclosure of the resistors shall have IP-34C degree of protection as per IEC-60529.
5. The metallic enclosure of the resistors shall be suitable to be installed on a steel reinforced concrete platform.
6. The metallic enclosure shall be rigid and robust.
7. The metallic enclosure of the resistors shall bear on its outer surface, located near the bottom, an earthing terminal for earthing purposes.
8. The resistor of the individual resistors which make-up the total resistor (if that is the case), shall be insulated from the frame of the enclosure by means of protection support post insulators.
9. The metallic enclosure of the resistor shall bear on its top ringbolts for easy handling and lifting.
10. The metallic enclosure shall be hot-dip galvanized and painted one prime coat and two finishing coats of synthetic enamel. The color shall be gray RAL 7040. The thickness of the painting shall be 60µm at least.

11. The incoming and out coming cables and outgoing copper strip shall enter into the metallic enclosure from its bottom.
12. The metallic enclosure shall have removable bolted panels on all of its four (4) sides so that there 'll be access to resistor from any of its four (4) sides.
13. The metallic enclosure shall consist of metal plates of 2mm in thickness.
14. The line-end bushing and the ground-end bushing shall be isolated from the resistor by installing them inside their own separate metallic compartment. In other words the main metallic enclosure shall contain two metallic compartments where the line-end bushing (terminal) and the ground-end bushing (terminal) shall be located at .
15. The compartment for the ground-end bushing shall have sufficient space so as to allow the installation of a current transformer of maximum dimensions of 35cmx25cmx20cm (WxHxD), which shall be used for the detection of the current through the resistor. Furthermore, it should be taken in to consideration that the distance of the live parts of the CT to the walls of the metallic enclosure must be at least 12cm.

VIII. REQUIRED RATED CHARACTERISTICS OF THE RESISTOR

- | | |
|---|---------------------------------|
| 1. Rated current (thermal current) | : 1000 A for 5 sec |
| 2. Rated time | : 5 sec |
| 3. Continues current | : 5 A |
| 4. Rated voltage | : 12 KV |
| 5. Resistance at 25°C | : 12 Ω |
| 6. Resistance tolerance | : $\pm 5\%$ |
| 7. Rated frequency | : 50 Hz |
| 8. Basic impulse insulation level (BIL) | : 125KV, Peak |
| 9. Power frequency with stand Voltage (dry and wet) | : 50KV, 50Hz, for one(1) minute |
| 10. Highest voltage (voltage insulation class) | : 24 KV |

IX. SUPPORT POST INSULATORS

The resistor or the individual resistors which make-up the total resistor (if that is the case) shall be insulated from the frame of the enclosure by means of indoor post insulators, which shall have the following characteristics:

- | | |
|---|--|
| 1. Type | : Indoor solid core type
post insulator |
| 2. Material of the insulator | : Porcelain |
| 3. Applicable standard for the insulators | : IEC-60273 |

4. Designation of the insulators as per IEC-60273	: J8-125
5. Power frequency withstand voltage dry	: 50 KV rms
6. Lightning impulse withstand voltage	: 125 KV peak
7. Height of the insulators	: 210 mm $\pm$ 1 mm
8. Maximum nominal diameter of insulating part	: 125 mm
9. Failing load	
▪ Po	: 8000 N
▪ P5o	: 6450 N

X. RESISTOR'S THERMOMETER

The resistor's enclosure shall be equipped with a dial type thermometer for the measurement of the resistor's temperature. This dial type thermometer shall have the following components and characteristics:

1. Type	: Dial type, Outdoor type weatherproof, water-tight
2. Method of installation	: The thermometer's front face shall be installed on the outside surface of the resistor's enclosure (flash mounting) and shall be located at such height as to be readable from ground level. The main body of the thermometer shall be inside the resistor's enclosure. Its sensing element (thermocouple) must be located close to the resistor in such a distance as to sense with as high accuracy as possible the critical temperature of the resistor and shall be supplied with the necessary suitable wire for transmitting the temperature.
3. Ambient operational temperature	: -25°C up to +45°C
4. Front face glass of the thermometer	: The front face glass shall be able to withstand the ambient operational temperatures of -25°C to +45°C without glass cracking or breaking.
5. Required features of the thermometer	: The thermometer shall be equipped with: <ol style="list-style-type: none"> A pointer for indicating the resistor's temperature continuously. A pointer for registering the maximum temperature of the resistor. The maximum pointer shall be resettable.

- c. A contact (NO) which shall be used to provide an alarm when the resistor's temperature reaches a level which the manufacturer considers to be critical to the resistor. This critical temperature must always be clearly indicated in the offer. By critical temperature it is meant that the resistor is not close to destruction, but its condition needs to be examined. This contact shall be voltage free and suitable for 110 V DC.
- d. A terminal block for the connection of the control cables which are to carry the alarm signal of the critical temperature to a panel inside the control building of the substation.

6. Thermometer's scale range

: The range of the scale of the thermometer shall be such as to accommodate the critical temperature of the resistor.

XI. RESISTOR'S LINE-END, GROUND-END TERMINALS AND HOW THEY ARE CONNECTED TO THE TRANSFORMER NEUTRAL AND TO EARTH

A. Line-end terminal (to be connected to the transformer neutral)

The connection of the resistor to the transformer neutral shall be realized by means of an indoor type bushing with the following characteristics:

- | | |
|---------------------------------|---|
| 1. Type | :Indoor type, dry solid type, porcelain bushing |
| 2. Highest voltage | : 24KV |
| 3. Rated phase-to-earth voltage | : 13.85KV |
| 4. Rated current | : 90 A |

5. Rated thermal short-time current	: 1000 A for 5 sec or 2250 A for 1 sec
6. Rated dynamic current	: 2500 A for 5 sec or 5625 A for 1 sec
7. Cantilever load withstand	: 500N
8. Insulating envelope	: the insulating envelope of the bushing shall be with sheds and of porcelain.
9. Lightning impulse withstand voltage	: 125 KV peak
10. Power frequency withstand voltage	: 50 KV rms
11. Type of material and shape of the bushing's terminals	: Copper, rectangular in shape, suitable to the connected to a 12/20/24 KV XLPE cable of cross section of 300mm ² .
12. Installation	: Inside a metallic compartment within the main enclosure of the resistor.

B. Ground-end terminal (used for the connection to ground (earth))

The connection of the resistor to the earthing (grounding) mat of the substation shall also be realized by means of an indoor type bushing which shall have the following characteristics:

1.Type	:Indoor type, dry solid type, porcelain bushing
2. Highest voltage	: 1.2KV
3. Rated phase-to-earth voltage	: 0.7KV
4. Rated current	: 90 A
5. Rated thermal short-time current	: 1000 A for 5 sec or 2250 A for 1 sec
6. Rated dynamic current	: 2500 A for 5 sec or 5625 A for 1 sec
7. Cantilever load withstand	: 500N
8. Insulating envelope	: the insulating envelope of the bushing shall be with sheds and of porcelain.
9. Lightning impulse withstand voltage	: 24 KV peak
10. Power frequency withstand voltage	: 6 KV rms
11. Type of material and shape of the bushing's terminals	: Copper, rectangular in shape, suitable to the connected to a tin-plated copper strip of 40mm x 40mm in dimensions
12. Installation	: Inside a metallic compartment within the main enclosure of the resistor

NOTE : The ground (earth) –end terminal of the resistor is fitted with an indoor type bushing because its potential is not the potential of earth due to the CT which is connected

between the ground end and earth (It is however, very close to earth potential). Furthermore, this enables isolated testing of the resistor and its components.

XII. TESTS

A. Routine Tests

1. Temperature coefficient of resistance

The resistor element resistance changes with temperature. The change may be calculated from the temperature coefficient of resistance according to paragraph 7.3 . IEEE Std C57.32a™-2020. It should be proven that the resistance of the NGR should not change by more than 67% from the initial value over the temperature range.

- 2. Measurement of the ohmic value of the resistor at an ambient temperature of +25°C.** If measurement is not possible at +25°C ambient, then the measurement shall be carried out at an ambient temperature of +10°C to +40°C and then the resistance value shall be adjusted to +25°C .
The measured value shall be $12 \Omega \pm 5\%$.

3. Applied potential test

Test voltage : 50KV, 50Hz, for one (1) min.

The test shall be carried out with the resistor completely assembled.

The test voltage shall be applied:

- Between line-end terminal and earth

- 4. Power frequency voltage dry test for the enclosure and conductive parts of the resistor.**

The voltage applied from the terminals of each section or assembly to its own enclosure shall be 2.25 times the rated value plus 2000 V when rated over 600 V (see Table 26 IEEE C57.32-2015)).for one (1) min.The test shall be applied between each conductive part (unit or frame) of the resistor and the enclosure which shall be earthed.

- 5. Visual and dimensional check.**
- 6. Check of the color of the enclosure and the thickness of its painting.**
- 7. Check of the space inside the enclosure to confirm that there is sufficient space near the ground-end terminal for the installation of a current transformer of 37cmx25cmx25cm (WxHxD) in dimensions.**

B. Type tests

(On one (1) resistor of the order which shall be selected randomly)

1. Temperature rise test

The test shall be carried out in ambient temperature of +10°C to +40°C

a) Steady state temperature rise test

This test shall be performed by applying rated voltage on the resistor until the temperature becomes constant, and then determining the hottest-spot

temperature rise. The temperature rise tests shall be made in a room that is essentially free from drafts.

The limits for the temperature rise shall be according to Table 25. IEEE Std C57.32a™-2020.

b) Less than steady state temperature rise test

This test shall be performed by applying rated voltage on the resistor for the rated time and then determining the hottest-spot temperature rise. The temperature rise tests shall be made in a room that is essentially free from drafts.

The limits for the temperature rise shall be according to Table 25 IEEE Std C57.32a™-2020.

The temperature rise tests shall be performed according to the time rating of the resistor.

Αύξηση θερμοκρασίας (C)		
Steady State for continuous current ratings	Steady state (hot-spot)	385
Rated Time for thermal current ratings less than Steady-State	Extended-time (hot-spot)	610
	Ten-minute (hot-spot)	610
	Less than 10 min (hot-spot)	760

. Table 25—Limiting temperature rises above 30 °C ambient for current carrying parts of neutral grounding resistors

3. Measurement of the impedance (Z_R) of the resistor.

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XII. DATA WHICH MUST BE SUBMITTED BY ALL BIDDERS

1. Outline drawing of the enclosure of the resistor, in which its physical dimensions are clearly depicted.
2. Cross section and top view of the enclosure with the resistor in it, so that all of its details are shown.
3. Brochures, technical pamphlets and any other information which is deemed necessary for the technical evaluation process.
4. All bidders are required to answer all items of **Attachment A**. Failure to comply, or partial filling of the attachment will constitute sufficient reason for rejection of the offer.
5. Any test certificates for same type resistors, for the type tests specified in this hereby technical description.
Acceptance or not of these certificates lies on IPTO's judgment.
6. A drawing indicating the space in which the current transformer is to be installed.
7. Detailed drawing for the thermometer, the bushings and post insulators.

XIV. DATA WHICH MUST BE SUBMITTED BY THE SUCCESSFUL BIDDER

1. Complete dimensional drawings and cross section and top view drawings of the resistor and its enclosure for approval before the construction (3 copies).
2. A drawing indicating the mounting of the resistor's enclosure on its concrete steel reinforced base.
3. Detailed drawing for the thermometer, for the bushings and for the post insulators for approval before construction of the resistor.
4. The supplier shall submit (if possible) the final "as manufactured" drawings in digital format, in (3) three copies for approval and (5) five copies at or before the time of shipment of the following:
 - a) The 3D model of the complete equipment shall be submitted in Autodesk AutoCAD format (dwg file), using 3D solids modelling, Alternatively, the 3D model can be submitted in Entegra Primtech 3D format. The 2D drawings of the equipment shall be also submitted in Autodesk AutoCAD format (dwg files), but also in in Adobe Acrobat format (pdf files).
5. All above Autodesk AutoCAD drawings should be open for editing and preferred to be submitted with digital sign by the manufacturer.

XV. WARRANTY

The supplier must provide a warranty of two (2) years, beginning from the date of delivery of the resistor, for damages due to faulty design, or due to unreliable components, or due to combination of the two.

XVI. PACKING

Each resistor shall be delivered fully assembled and inside a robust wooden box.

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THE NEUTRAL OF 150/20KV TRANSFORMERS****ATTACHMENT "A"**

Failure to provide all information will result in rejection of the offer.

1. Manufacturer :.....
.....
2. List all applicable standards for the resistor and its metallic enclosure :.....
.....
.....
.....
3. List ambient temperature range in which the resistor can operate without problems :.....
4. Characteristics of the resistor material:
 - a. Designation :.....
 - b. Main composition :.....
 - c. Resistivity at 25°C :..... Ω
 - d. Temperature coefficient :...../ °C
 - e. Maximum temperature rise of the resistor at +25°C ambient temperature :..... °C
 - f. Melting temperature of the resistor :..... °C
 - g. Maximum temperature rise of the resistor at +45°C ambient temperature :..... °C
5. Critical temperature of the resistor at which an alarm via thermometer shall be produced :..... °C
6. Is the resistor self-cooled, of the outdoor

- type and installed in a metallic enclosure? :.....
7. Degree of protection of the metallic enclosure
as per IEC-60529 :.....
8. Is the resistor's metallic enclosure suitable
to be installed on a steel reinforced
concrete platform: :.....
9. Is the resistor's metallic enclosure equipped
with an earthing terminal located near its
bottom for earthing purposes? :.....
:.....
10. Is the resistor or the individual resistors which
make-up the total resistor, insulated from the
frame of the enclosure by means of porcelain
support post insulators? :.....
11. Is the resistor's enclosure equipped with
ringbolts for easy handling and lifting? :.....
12. Is the resistor's enclosure hot-dip galvanized?:.....
13. Is the resistor's enclosure painted with one
prime coat and two finishing coats of
synthetic enamel? :.....
:.....
:.....
14. Is the color of the resistor's enclosure
gray RAL 7040? :.....
15. Thickness of the painting :.....
16. Can the incoming and outcoming cables
enter from the bottom of the resistor's
enclosure? :.....
:.....
:.....
17. Are the panels on the four (4) sides of
the enclosure removable through bolts? :.....
:.....

18. Does the resistor's metallic enclosure consist of metal plates of 2mm in thickness :.....
19. Rated characteristics of the resistor
- a. Rated current (thermal current) :.....
 - b. Rated time :.....
 - c. Continuous current :.....
 - d. Rated voltage :.....
 - e. Resistance at +25°C :.....
 - f. Resistance tolerance :.....
 - g. Rated frequency :.....
 - h. Highest Voltage
(voltage insulation class) :.....
 - i. Basic impulse insulation level :.....
 - j. Power frequency voltage withstand :.....
20. Characteristics of the support post insulators
- a. Type :.....
:.....
:.....
 - b. Material of the insulator :.....
 - c. Applicable IEC standard for the support
insulators :.....
 - d. Designation as per IEC-60273 :.....
 - e. Power frequency voltage
withstand, dry :.....
 - f. Lightning impulse withstand voltage :.....

- g. Height of the insulators :.....
- h. Maximum nominal diameter of the insulating part :.....
- i. Failing load
 - a. P_o :.....
 - b. P_{5o} :.....
- 21. Resistor's thermometer data
 - a. Type :.....
 - b. Describe the method of installation of the thermometer on the front side of the resistor's enclosure? :.....
 :.....
 :.....
 :.....
 :.....
 :.....
 - c. Is the thermometer readable from ground level? :.....
 - d. Ambient operational temperature range of the thermometer :.....
 - e. Is the thermometer face glass capable of withstanding temperatures of -25°C to $+45^{\circ}\text{C}$ without cracking or complete breaking? :.....
 :.....
 :.....
 - f. Is the thermometer equipped with a pointer for indicating the resistor's temperature? :.....
 - g. Is the thermometer equipped with a

- pointer for registering the maximum temperature of the resistor? :.....
- h. Is the pointer for registering the maximum temperature resetable? :.....
- i. Is the thermometer equipped with a contact which shall provide an alarm, if the resistor reaches a critical temperature? :.....
- j. Is the above contact free of voltage and suitable for 110V DC? :.....
- k. Is a terminal block provided for the connection of the control cables which shall carry the alarm signal of the critical temperature? :.....
- l. Range of the thermometer scale :.....
22. Bushing characteristics used in conjunction with the resistor's line –end terminal
- a. Bushing type :.....
:.....
:.....
- b. Highest voltage :.....
- c. Rated phase-to-earth voltage :.....
- d. Rated current :.....
- e. Rated thermal short-time current :.....
- f. Rated dynamic current :.....
- g. Insulating envelope material and indicate if it is with sed :.....
:.....
:.....
:.....
- h. Lightning impulse voltage withstand :.....

- i. Power frequency voltage withstand :.....
- j. Type of material and shape of the bushing's terminal :.....

- k. Cantilever load withstand :.....
- l. Manufacturer :.....
- 23. Bushing characteristics used in conjunction with the resistor's ground-end terminal
 - a. Bushing type :.....

 - b. Highest Voltage :.....
 - c. Rated phase-to-earth voltage :.....
 - d. Rated current :.....
 - e. Rated thermal short-time current :.....
 - f. Rated dynamic current :.....
 - g. Insulating envelope material and indicate if it is with sed's :.....

 - h. Lightning impulse voltage withstand:.....
 - i. Power frequency voltage withstand :.....

- j. Type of material and shape of the bushing's terminal :.....

- k. Cantilever load withstand :.....
- l. Manufacturer :.....
24. Dimensions of the resistor's enclosure :.....
25. Weight of the resistor along with its enclosure :.....
26. Is the critical temperature of the resistor identical to the maximum temperature rise of the resistor at +25°C? :.....

27. Warranty period which shall begin from the delivery date :.....
28. Are the line-end and ground-end bushing terminals installed in their own separate compartments? :.....
29. Does the ground-end bushing terminal compartment have sufficient space for the installation of a indoor type CT of maximum dimensions of 35cm x 25cm x 20cm and also taken into considerations clearances? :.....