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Research Designs & Standards Organisation
Manak Nagar, Lucknow – 226 011

Technical Instruction No.: TI/IN/0030

Technical instructions related to the installation and commissioning of the 42 kV Metal oxide gapless Lightning Arresters provided on Traction systems on Indian Railways

Important points related to the installation and commissioning of the 42 kV Metal oxide gapless Lightning Arresters

1.0 Background

Functioning of the 42 kV lightning arresters (provided on 25 kV side) to a large extant depends upon its correct installation. Similarly it is important to understand the construction and working of the Lightning Arresters to fully appreciate its failure modes and importance of the installation and commissioning aspects. Failures of 42 kV LA's are on higher side as compared to the LA's provided on HV supply at TSS. Some failures of Lightning Arresters are reported from Railways however the failure investigation part is generally missing therefore investigation of failed LA's is also covered in this instruction.

1.1 Historical developments related to the provision of 42 kV class LA's over IR

1.1.1 Gapless Metal Oxide Lightning arresters are compulsorily provided at all the Traction substations and switching posts. The LA's provided at TSS are for protection of equipment there while LA's provided at SP/SSP mainly acts to divert travelling surges on OHE. Lightning Arresters provided at AT locations were gradually removed from 1982 onwards due to the reliability issues associated with them.

1.1.2 Subsequently instructions were issued to SER, ER, ECR & SECR in 1/2005 for providing LA's before selected lightning prone AT locations and furnish performance to RDSO for further study of the issues. Afterwards, based on encouraging results submitted by Railways extensive trials of LA's at selected AT locations under lightning prone areas were advised to all Railways in 9/2006 & reiterated in 7/2008.

1.1.3 After field trials in above 100 locations, SR suggested provision of an additional arcing horn (gapped at 165 mm) at 9 - Tonne insulator prior to DO fuse of AT lightning prone areas in 8/08. Reduction in the cases of DO fuse blowing cases was confirmed by S.Rly. Subsequently on advise of RB, RDSO examined the issue and submitted its recommendations of providing additional arcing horns and monitor its performance to RB on 1/2009 which was approved in 7/2009 and RDSO issued a scheme of providing arcing horn at 9-T insulator prior to AT, to all Railways in 2/2010 and periodical performance feedback was requested.

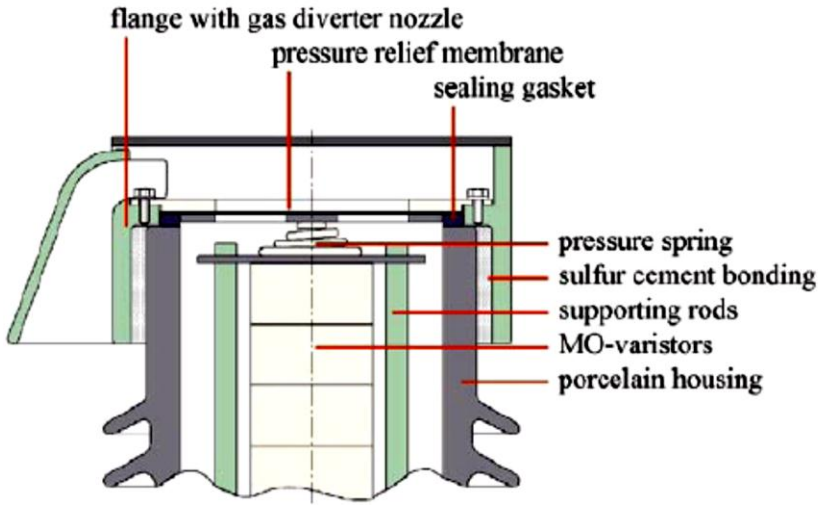
2.0 Other relevant RDSO documents and standards on LA maintenance

Document/Standard	Subject
RDSO specification No. TI/SPC/PSI/MOGLA/0100 (07/10)	Technical specification for metal oxide gapless type lightning arrester for use on 25 kV side of Railway traction substations and switching stations.
RDSO specification No. TI/SPC/PSI/LCMLA/0030 revision 1 (07/10)	Technical specification for leakage current monitor for lightning arresters.

RDSO Maintenance Instruction No. TI/MI/0041 Rev.1	Maintenance Instruction for lightning arresters.
IEC 60099-4	Metal oxide Surge arresters without gaps for a.c. system
IS 3070 part-III	Lightning arresters for alternating current system – specification – part 3: Metal oxide lightning arresters without gaps

3.0 Construction & working of the Lightning Arresters

A high voltage surge arrester basically consists of a stack of cylindrical MO elements kept together by a supporting structure and a housing. The main parts of arrester are its porcelain housing, Metal Oxide resistor blocks, pressure relief mechanism, spring mechanism to hold MO blocks and sealing arrangement as shown in the diagram below.



The general purpose of the housing is to:

(i) Protect the MO elements from environmental impacts such as humidity and pollution as well as damages due to transport,
(ii) Carry external forces, e.g. by conductor wires, wind or earthquake
(iii) Control the pressure relief behavior in case of electrically overloading the arrester,
(iv) Provide a dielectric strength (withstand voltage) above the protection level of the arrester and to
(v) Keep the stack of MO elements together by maintaining a certain pressure within the stack.

A very important part of above design MO surge arresters with respect to safety and reliability is the sealing and pressure relief system. The sealing system is designed to prevent ingress of moisture for the whole lifetime of LA i.e. 15 years. Similarly the

porcelain housing is designed to withstand the internal pressure and arc heat and remain mechanically undamaged during flow of short circuit current and pressure relief.

3.1 Failure modes of Lightning arresters

Most of the LA failures are caused by deficiency of the sealing system due to transportation damage or perishing of rubber sealing gasket due to ageing. Another mode of failure may be, stressing the arrester above its specification, e.g. by direct lightning strokes with extremely high currents or by voltage transfer.

In case of an arrester failure and internal short circuit, the pressure relief system must release the pressure inside the housing which is caused by the arc heat before the housing is violently destroyed by the pressure shock wave. Furthermore, the pressure relief forces the arc out of the housing to prevent from further pressure built-up and burning of the internal parts and housing.

It must be noted that failure of an arrester is a very rare event. Gapped SiC (Silicone carbide) surge arresters used to fail quite frequently and these are now mostly replaced by modern Metal Oxide gapless surge arresters, failure rates of which are considered much lower.

Under normal circumstances (@ operating voltage, without presence of surge) a very low leakage current flows through the LA however with the ingress of moisture and deterioration of MO blocks it goes on increasing finally causing its short circuiting (due to internal losses & heat generation).

4.0 Important points related to the Installation & commissioning of Lightning Arresters

4.1 National/international earthing codes, standards & manuals stipulate requirements for good earthing for lightning surge arresters as explained below.

- IEEE- 80 Clause 17.7 stipulates that “Surge arresters should always be provided with a reliable low-resistance ground connection. Arresters should be connected as close as possible to the terminals of the apparatus to be protected and have as short and direct a path to the grounding system as practical. While many utilities provide separate ground leads from arresters mounted on metal structures, other utilities use the arrester mounting structures as the surge arrester ground path because the large cross section of the steel members provides a lower resistance path than a copper cable of the usual size. In these cases it is important to ensure adequate electric connections from the structure to both arrester ground lead and ground grid; and also to be sure that the steel cross sectional area is adequate for conductivity, and that no high resistance is introduced into joints from paint films, rust, etc.”

- Article 280 of National Electricity code (NEC) of NFPA 70 also defines installation of the surge arresters i.e. Para 280.12 *Routing of Surge Arrester Grounding Conductors- “*The conductor used to connect the surge arrester to line, bus, or equipment and to a

grounding conductor connection point as provided in 280.21 shall not be any longer than necessary and shall avoid unnecessary bends." Size of the lead prescribed is not less than 6 AWG Cu or Al.

- IE rules (Para 92- 2) also recommend that the earthing lead for any lightning arrestor shall not pass through any iron or steel pipe, but shall be taken as directly as possible from the lightning-arrestor to a separate earth electrode and/or junction of the earth mat already provided for the high and extra high voltage sub-station subject to the avoidance of bends wherever practicable.

- Code for Earthing Traction Power Supply Installation" vide Appendix III of ACTM Vol-II part-II (ETI/PSI/120(2/91)) clearly states the earthing arrangements of LA at TSS, SSP/SP which should be followed.

4.2 Higher grounding resistance causes large voltage drop when lightning discharge current passes through it thereby stressing the insulation voltage withstand capabilities of Surge arrester.

4.2.1 The length of HV and earth connection leads need to be short and as straight as practical in order to minimize the loop inductance and ensure minimum voltage drop across the leads. The inherent resistive and inductive impedance in the leads increases the effective residual voltage seen by the equipment being protected. This issue is particularly sensitive for protection from fast-front over voltages. Therefore it is important to keep these lead lengths short and free of inductive loops.

4.3 The cross-sectional area of the connecting leads is determined more by mechanical than by electrical requirements. Due to the very short time of discharge current flow, power or energy consumption in the conductor plays lesser role even though the currents may be high. If LA's are placed on an insulating base (as recommended in RDSO specification for Traction Installation also) then it is connected to earth by a 35 $mm^{2,}$ 1100 volts grade, unarmored PVC insulated copper cable. This arrangement has got advantage of measurement of leakage currents for condition monitoring however this lead introduces an inductance in to the lightning discharge circuit.

4.4 In Railway traction installations like SP, SSP and AT's where LA's are fitted on gantries & masts, length and connection of grounding leads is very important.

4.5 Maximum permissible earthing resistance at AT locations is 10 Ω as compared to 0.5 & 2 Ω at TSS & SP/SSP.

It is therefore recommended that if it is decided to provide LA at AT location then a separate earthing pit should be provided and LA earthing lead should be directly connected to this independent earthing and bonding it to the earthing arrangement at AT location as per Para 11 of the Code for Earthing Traction Power Supply Installation" vide Appendix III of ACTM Vol-II part-II (ETI/PSI/120(2/91)) to achieve earthing resistance comparable to SP/SSP.

4.6 While storing and transporting Lightning Arresters it should be ensured that these are kept vertical with porcelain sheds pointing downwards to prevent any ingress of moisture inside. In any case, the precautions specified by the manufacturer for transportation and storage should strictly be followed as porcelain-housed arresters are very sensitive to transportation stress, which often represents the highest mechanical stress during an arrester's lifetime.

5.0 Failure investigation of the Lightning Arresters

A format recommended for failure investigation of LA's is given below:

	Check points	**Remarks**
1	Location of LA (TSS/SP/SSP or at AT)	• Check that there are no repeated failures from same location. If so check earthing and connections to LA.
2	Weather conditions at the time of LA failure	• Most of the LA failures occur during rainy (lightning) season however failure even during dry conditions must be jointly recorded with the manufacturer.
3	Make & year of manufacturing and commissioning	• Ascertain age of LA, compare from codal life. • Repeated failures of one particular make, batch of LA's. Report to manufacturer & CORE/Ald. • Failure immediately after installation may be either due to poor quality of LA or installation related issues.
4	Earthing Resistance at the point where LA's earth terminal is connected	• Check from records & whether it is a high earth resistance area. Any special efforts done to reduce earth resistance.
5	Length of Earthing lead from LA's to Earth terminal	• Connections should be as short as possible.
6	Size/cross section of Earthing conductor used as earthing lead for LA's	• As per LA specifications and Para 7.6 & 8.3.3 of Code for Earthing Traction Power Supply Installation" vide Appendix III of ACTM Vol-II part-II (ETI/PSI/120(2/91)).
7	Distance of LA's from earth terminal	• Connections to earth should be as short as possible.
8	Distance of failed LA at SP/SSP from TSS	• LA's at SP/SSP are practically protecting OHE.
9	Last values of following measurements (i) Total leakage current of LA (ii) Resistive leakage current. (iii) Surge counter readings	• Check for any trends of deterioration in condition of LA. • Review the threshold (limiting values) of resistive leakage current for replacement.

10	Any flash mark observed at the site on LA/Mast etc.	• Signs of a direct lightning strike on or near the LA location.
11	Bonding condition (whether any flash mark observed)	• Signs of a direct lightning strike on or near the LA location.
12	Whether LA was with or without insulating base	• It is important to have a proper connecting lead for LA's with insulating base.
13	Whether burst or simply earth	• Cases of LA bursting indicate failure of its pressure relief mechanism & should therefore be informed or recorded in the joint minutes with the manufacturer. • Instead of bursting of housing, opening of the top cover indicates that its pressure relief mechanism worked.
14	Any flashing marks on the outer surface of the porcelain LA housing	• Check record of cleaning done on housing.
15	Condition of its electrical terminal connections at top (live) & bottom (to earth/surge counter/leakage current meter)	• Look for any breakage, flashing signs.
16	Joint report with the manufacturer	• If failed LA is not burst then break open it in presence of manufacturer and check signs of water leakage up to MO blocks and damage/condition of MO blocks.