Government of India

सत्यमेव जयते

Ministry of Railways

Research Designs & Standards Organisation

Manak Nagar, Lucknow - 226011

MAINTENANCE INSTRUCTION NO. TI/MI/0041 Rev. 1

Maintenance Instructions

for

Condition monitoring of Lightening Arresters provided on traction systems on Indian Railways

1. Scope:

The technical instructions compiled in this document are related to the different aspects of the condition monitoring of lightening arresters including measurement of resistive leakage current as applicable to metal oxide gapless type lightning arresters of different voltage class existing on traction system of IR.

2. Objectives :

Objective of these instructions is to develop awareness about the condition monitoring of Lightening Arresters of different voltage class

3. Introduction

3.1 Applicable standards for Lightening & surge arresters

These instructions are based on following standards, specifications and RDSO documents issued in past:

S.No.	Standard/reference	Subject
a.	IEC 60099-1, 3, 4	Different types of surge/lightening arresters
b.	IEC 60099-5	Surge arresters-selection & application recommendation
c.	IS 3070 part-3	Lightning Arresters for Alternating Current Systems - Specification - Part 3: Metal Oxide Lightning Arresters without Gaps.
d.	IS 15086 part-3	Selection & application guide
e.	RDSO specification No. TI/SPC/PSI/LCMLA/0030	for Third Harmonic resistive Current measurement equipment
f.	RDSO instructions TI/MI/0041 dated 27-09-05	Maintenance instructions for Lightening Arresters

3.2 Diagnostic Indicators of metal oxide Surge Arresters in service.

Except for brief occasions when a surge arrester is functioning as an over voltage-limiting device, it is expected to behave as an insulator therefore its insulating properties are most essential for operational reliability of the power system.

Different diagnostic methods and indicators for revealing possible deterioration or failure of the insulation properties have been tried since the introduction of surge arresters. These methods range from fault indicators and dis-connectors for indication of complete arrester failures, to instruments that are able to measure slight changes in the resistive leakage current or the power loss of metal oxide arresters.

3.2.1 Fault indicators

Fault indicators provide a clear visual indication of a failed arrester, without disconnecting the arrester from the line. They may be an integrated part of the arrester, or a separate unit installed in series with the arrester. The working principle is usually based on the amplitude and duration of the arrester current, or on the temperature of the non-linear metal-oxide resistors.

3.2.2 Dis-connectors

Dis-connectors, often used on medium-voltage arresters, provide a visual indication of a failed arrester by disconnecting it from the system. The typical working principle is an explosive device triggered by the fault current: however, the dis-connectors are not intended to extinguish the fault current. The dis-connector may be an integral part of the arrester or insulating bracket, or a separate unit installed in series with the arrester. The advantage is that the line remains in operation after disconnection of the arrester. The major disadvantage is the lack of overvoltage protection until the failed arrester has been discovered and replaced.

3.2.3 Surge counters

Surge counters operate at impulse currents above certain amplitude, or above certain combinations of current amplitude and duration. If the interval between discharges is very short (i.e. less than 50ms), surge counters may not count every current impulse. Some counters are not so sensitive and may not count the short impulse currents through metal-oxide arresters.

Depending on the operating principle and sensitivity of the counter, it may give an indication about over voltages appearing in the system, or it may provide information on the number of discharges corresponding to significant arrester energy stresses. The counter provides no specific information about the condition of the arrester.

The arrester with surge counters are equipped with an insulated earth terminal and a conductor between the arrester and counter that is insulated from earth. For safety reasons, the surge counter should be installed beyond easy reach of personnel; it shall be located where it can be read from ground level with the arrester in service. The installation should be provided with shortest length of the earth connection without reducing its cross-section.

3.2.4 Monitoring spark gaps

Monitoring of spark gaps is done to indicate the number and estimate the amplitude and duration of discharge currents through the arrester. Special experience is necessary to properly interpret the marks on the gap. Some spark gaps can be examined with the arrester in service, while other types require that the arrester is de-energized. It is required that the arrester be equipped with an insulated earth terminal. Alternatively, the device should be an integral part of the arrester. Spark gaps give no direct information about the actual condition of the arrester, but may help to make decisions about continued operation.

3.2.5 Temperature measurements

Remote measurement of the arrester temperature can be carried out by means of thermal imaging methods. The measurements are only indicative with regards to the condition of the arrester, since the temperature drop between the resistors and the housing surface may be substantial. Nevertheless, comparative measurements made on adjacent arresters or arrester units may indicate excessive heating.

Direct measurements of the metal-oxide resistor temperature may give an accurate indication of the condition of the arrester, for this it is essential that the arrester should be equipped with special transducers at the time of manufacturing. Therefore, this method is used only in special arrester applications.

3.2.6 Leakage current measurements of metal-oxide arresters

Any deterioration of the insulating properties of a metal-oxide arrester causes an increase in the resistive leakage current or power loss at given values of voltage and temperature. The majority of diagnostic methods for determining the condition of gapless metal-oxide arresters are based on measurements of the leakage current.

The measuring procedures can be divided into two groups: on-line measurements, when the arrester is connected to the system and energized with the service voltage during normal operation, and off-line measurement, when the arrester is disconnected from the system and energized with a separate voltage source on site or in a laboratory.

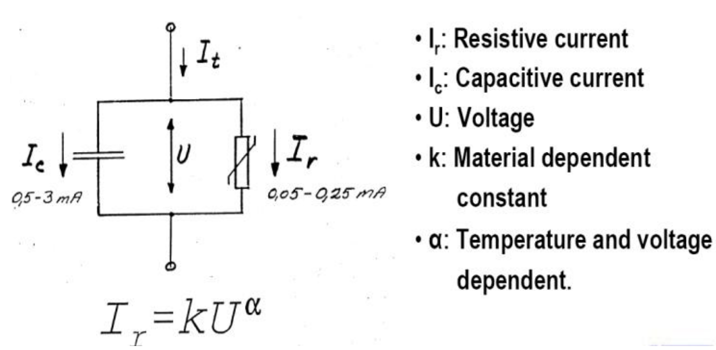
Off-line measurements can be made with voltage sources that are specially suited for the purpose, e.g. mobile ac or dc test generators. Good accuracy may be obtained by using the off-line methods, provided that a sufficiently high test voltage is used. The major disadvantages are the cost of the equipment and the need for disconnecting the arrester from the system.

Measurements carried out on-line under normal service voltage are the most common method. For practical and safety reasons, the leakage current is normally accessed only at the earthed end of the arrester. To allow measurements of the leakage current flowing in the earth connection, the arrester must be equipped with an insulated earth terminal.

Out of the monitoring methods mentioned above leakage current monitoring especially the monitoring of resistive leakage current is most popular and same has been adopted in IR and discussed in detail in Para's below.

4.0 Properties of the leakage current of nonlinear metal-oxide resistors

The ac leakage current can be divided into capacitive and resistive part, with a pre-dominant capacitive component and a significantly smaller resistive part.



4.1 Capacitive leakage current

The capacitive leakage current measured at the earth terminal of an arrester is caused by the permittivity of the non-linear metal-oxide resistors, the stray capacitances and the grading capacitors, if applied. The specific capacitance of a resistor element typically results in a capacitive peak leakage current of about 0.5mA to 3mA under normal service conditions.

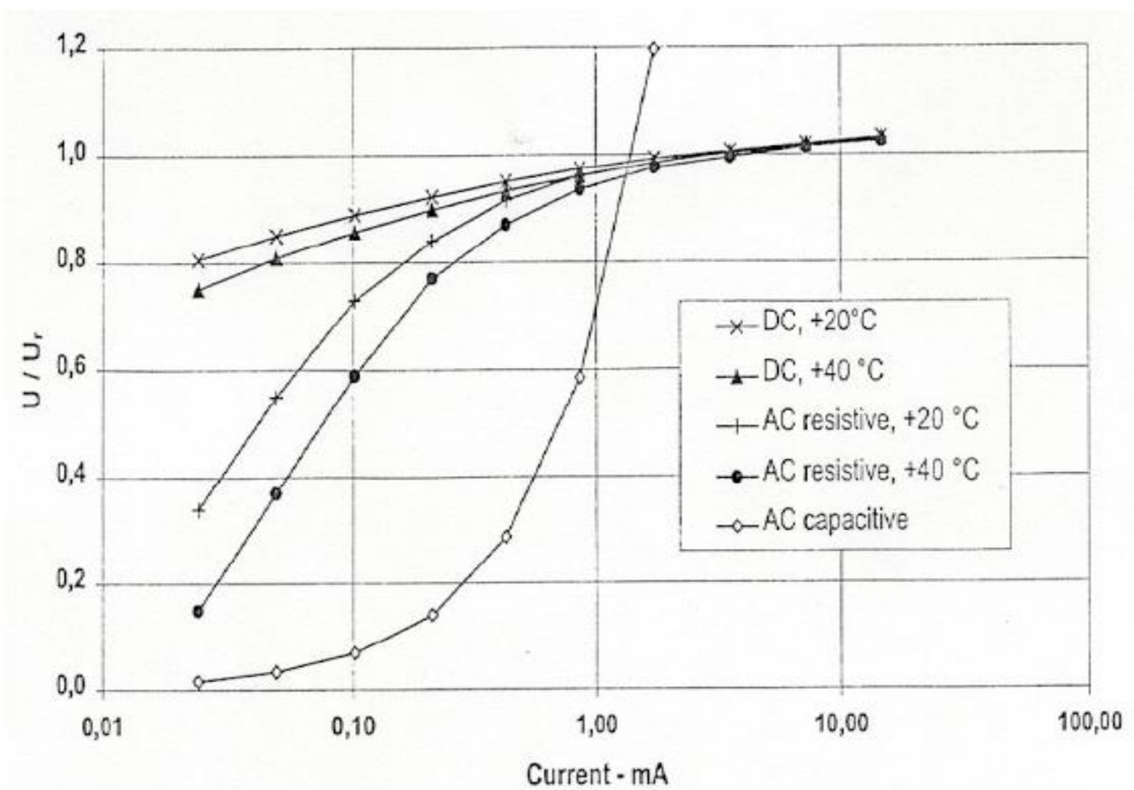
The capacitive current does not change significantly due to deterioration of the voltage-current characteristic of the non-linear metal-oxide resistors. Therefore, its measurement cannot reliably indicate the condition of metal-oxide arresters.

4.2 Resistive leakage current

At given values of voltage and temperature, the resistive component of the leakage current is a sensitive indicator of changes in the voltage-current characteristic of non-linear metal-oxide resistors. The resistive current can, therefore, be used as a tool for diagnostic indication of changes in the condition of metal-oxide arresters in service.

The resistive component under ac voltage is defined as the current level at the instant of voltage maximum (d_U/d_t=0). The resistive leakage current of a non-linear metal-oxide resistor is in the order of 5% to 20% of the capacitive current under normal operating condition, corresponding to about 10µA to 600 µA peak at a temperature of ±20^0C.

In the leakage current region, the resistive current depends on the voltage and temperature. Typical curve indicating voltage and temperature dependencies for different components of leakage current is shown below.



4.3 Harmonics in the leakage current

The non-linear voltage-current characteristic of a metal-oxide arrester gives rise to harmonics in the leakage current when the arrester is energized with a sinusoidal voltage. The harmonic content depends on the magnitude of the resistive current and the degree of non-linearity, which is a function of voltage and temperature. As an example, the third harmonic content of the resistive current is typically 10% to 40%. The harmonic content can, therefore, be used as an indicator of the resistive current.

Another source of harmonics, beside negligible ones, that may considerably influence the measurement of harmonics in the leakage current, is the harmonic content in the system voltage. The capacitive harmonic currents produced by the voltage harmonics may be of the same order of magnitude as the harmonic currents created by the non-linear resistance of the arrester. This aspect is very important in case of Traction load which is a big source of harmonic distortion with predominant 3rd Harmonic contents of up to 20 % in current.

4.4 Surface leakage current

As with any other outdoor insulator, external surface leakage current may temporarily occur on the arrester housing in rain or in conditions of high humidity combined with surface pollution. In addition, internal surface leakage current may also appear due to moisture penetration. During measurements, the surface currents may interfere with the leakage current of the resistors, however, the sensitivity to external and internal surface currents may be different for the various measurement methods. The influence of the external surface leakage current can be avoided, either by performing the measurements in dry conditions, or by any other suitable method, e.g. bypassing the surface leakage current to ground.

5.0 Measurement of leakage currents

5.1 Measurement of total Leakage Current (To be adopted on IR)

The total leakage current depends mainly on the capacitive current, since the resistive part is only a fraction of the capacitive current component. Furthermore, the capacitive and resistive current components differ in phase by 90^0, therefore, a large increase in the resistive current of the non-linear metal-oxide resistors is needed before a significant change can be noticed in the total leakage current level. In addition, the total leakage current is sensitive to the installation, since the capacitive current depends on the stray capacitances.

On-line measurements of the total leakage current are extensively used in practice by means of conventional mA-meters built into the surge counters or into portable instruments, showing the r.m.s., mean or peak value of the total leakage current. However low sensitivity to changes in the resistive current level makes the measurement of total leakage current not reliable as a diagnostic indicator.

5.2 Measurement of Resistive Leakage current

As per IEC 60099-5 there are number of direct and indirect methods specified for measurement of the resistive component of the leakage current. Out of these, B-2 method involving “Third harmonic analysis with compensation for harmonics in the system voltage” has so far been recommended for traction system on IR.

Method B-2 -Third order harmonic analysis with voltage harmonics compensation

The method is based on the fact that harmonics are created in the leakage current by the non-linear voltage-current characteristic of the arrester. It is assumed that all harmonics arise from the non-linear resistive current. The harmonic content depends on the magnitude of the resistive current and on the degree of non-linearity of the voltage-current characteristic, i.e. the harmonic content varies also with the voltage and temperature of the arrester.

The third harmonic is the largest harmonic component of the resistive current, and it is the most commonly used for diagnostic measurements. The conversion from harmonic to resistive current level, if required, relies on information supplied by the arrester manufacturer or from measurements in the laboratory.

The method can be readily used for measurements in service. The main problem is the sensitivity to harmonics in the system voltage. The harmonics in the voltage create capacitive harmonic currents that are comparable in size with the harmonic currents generated by the non-linear resistance of the arrester. As a result, the error in the measured harmonic current may be considerable if the harmonic content in the voltage is high. However the sensitivity to harmonics in the voltage is greatly reduced by the introduction of a compensating current signal for the capacitive third harmonic current in the arrester. The compensating current signal is derived from a “field probe” positioned at the base of the arrester. After proper scaling, the harmonic current induced in the probe by the electric field is subtracted from the total harmonic current. The result is the harmonic current generated by the non-linear resistive current of the arrester. The conversion from third harmonic to resistive current requires additional information from the arrester manufacturer. The method is suitable for measurements in service.

6.0 Condition monitoring of lightening arresters in traction system

6.1 General recommendations to be adopted on IR

6.1.1 It is noticed worldwide that reliability of lightning arresters can be improved by taking precautions e.g. periodical monitoring of the health of arrester by checking the possible deterioration and identifying the defects in initial stages.

6.1.2 Failure of lightning arresters takes place mainly due to ingress of moisture inside lightning arresters and / or ageing of zinc oxide blocks.

6.1.3 Leakage current measurement can be done only on lightning arresters fitted with porcelain insulated base of the same mounting dimension as that of the lightning arrester.

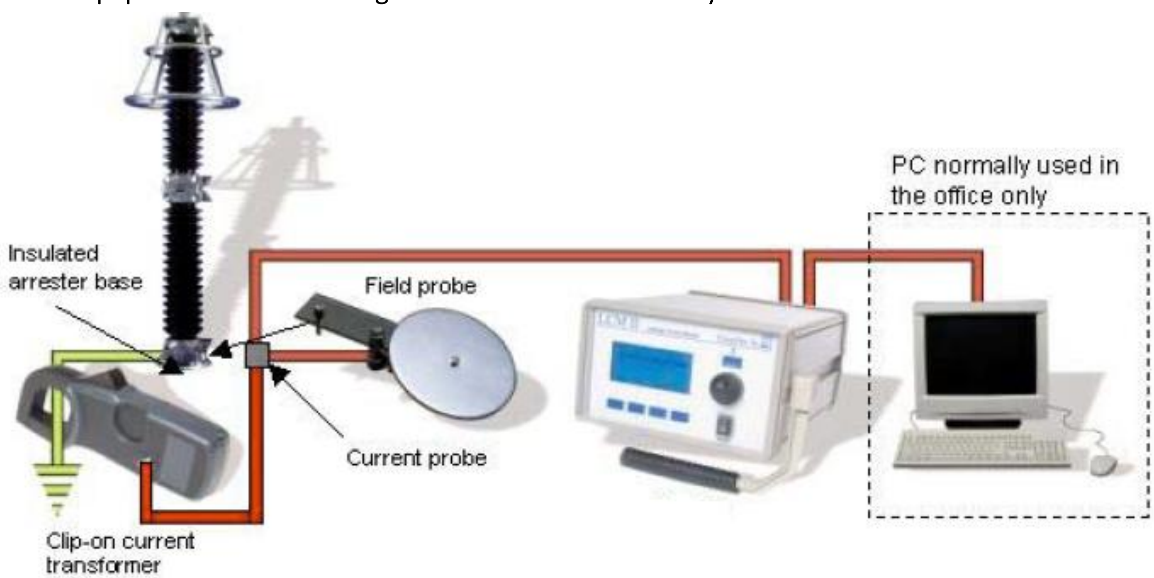
6.1.4 If surge monitors are provided for lightning arresters the connection from lightning arrester base to surge monitor unit/earth terminal should be made through a small piece of 35 mm^2, 1100 volts grade, unarmored PVC insulated copper cable to facilitate on line measurement of leakage current. For 25 kV side LAs at FP/SSP/SP, surge monitor shall be provided on the uprights of the gantries at a height of 1.5 meter to facilitate monitoring of leakage current through surge monitor and on line measurement of third harmonic leakage currents.

6.1.5 IR value of lightning arresters should be measured during annual maintenance and it should be above 1.0 G ohms (for 42 kV LAs on 25 kV side) and more than 10 G ohms (for LAs on HV side). The IR measurement should be done by 2.5/5.0 kV equipment. In the periodic maintenance, connections on HT side and earth side have to be checked and ensured in proper condition.

6.1.6 The checks and maintenance as indicated in **Annexure-I** are to be done at time of receipt, before commissioning and during maintenance of the lightning arrester.

6.2 Measurement of resistive current

6.2.1 As explained above the degradation of metal oxide lightning arresters in service can be diagnosed by estimating resistive part of the total leakage current using the third harmonic analysis with compensation for voltage distortion. Third harmonic analysis based assessment of resistive component of leakage current is recorded by sophisticated equipment. The block diagram of the measurement system is shown below.



6.2.2 Assessment of resistive component of leakage current is a very sensitive measurement due to its small value (few micro amperes) and its dependence on Voltage and temperature. Every reading recorded is also accompanied by the Voltage and temperature at the time of reading.

6.2.3 The measurements should be taken preferably under dry climatic conditions to avoid interference with surface leakage currents. It is suggested to complete one cycle of measurements prior to onset of monsoon.

6.2.4 The calibration of the equipment should be checked with the equipment manufacturer. The readings recorded should be carefully examined for consistency of results e.g. very high leakage currents for all LA's at one place or wide variations in repeated measurements needs cross verification.

6.2.5 The antenna of the equipment is to be kept at the foot of the LA base. In case LA's are provided on gantries and if at such height it is not possible to place antenna, the antenna can be placed at the base of any nearby PT or base insulator connected in the same circuit.

6.2.6 Features, operating instructions and displays of different equipment manufacturers may vary widely therefore it is suggested that end user must get proper training from the manufacturer. Generally the resistive leakage current monitoring equipment may provide:

I_t –Total leakage current (mA)
I_c – Capacitive component of leakage current (mA)
I_{3t} –Third harmonic component of leakage current (µA)
I_r –Resistive component of leakage current (µA)
I_r corr. – corrected value of I_r after considering effect of temperature (µA)

6.2.7 As pointed out in Para's 4.3 & 5.2.1, this method of measurement is extremely sensitive to the harmonic distortion present in the supply. The antenna probe picks up the harmonic distortion levels for its compensation however as traction load current contains high content of third harmonic which results in to voltage distortion also, it is observed in field that number of times the equipment fails to record any reading and may also repeatedly display an error. There are more chances of such incidences when the traction load is present. In such conditions, if possible measurements may be planned at no load/ light load condition.

6.2.8 Records of periodic maintenance and measurement of each lightning arrester should be maintained including location, rating, make, serial no., date of manufacturing, date of commissioning, date of measurement, IR value, value of resistive leakage current, total leakage current, No. of surges passed and maintenance remarks.

6.2.9 The value of resistive leakage current shall be recorded and in case of abrupt variation or very high leakage current, the concerned lightning arresters should be taken out from the service for detailed investigation. It is also suggested that some such arresters should be jointly examined with the arrester manufacturer to identify the cause of deterioration so that improvements in the design can be made. The data bank of different makes and ratings of arresters may also be made for fixing the maximum value of permissible leakage currents for each type/make.

A comparative study of results shall indicate the deterioration in the condition of arrester. RDSO has summarized the data of measurements received from Railways and based on which, it is suggested that LA's with resistive leakage currents in between 350-500 µA should be closely monitored and beyond 500 µA should not be permitted & removed from service at the earliest.

The limits prescribed above are based on limited experience of Railways & data collected from other utilities; however same shall be further reviewed based on feed backs received from Railways. It is therefore advised that proper data/statistics should be maintained by Zonal Railways, traction sub-station wise and report should be sent to RDSO in the enclosed Annexure-II for further study, review & modification required, if any.

Annexure-I

Stage of checking	Items to be checked	Type of check & Instruments to be used	Records and standards	Activities and measurements / observations	Remarks
At time of receipt	Lightning arrester unit and accessories including insulating base, surge monitor	Visual check on condition of crate. Dimensional verification	Packing list/invoice Approved drawings	Check for any damage to crates, arrester units and accessories as per packing list / invoice. Item shall be as per approved drawings.	Advise firm in case of shortage, damage and mismatch in dimensions to arrester units as well as accessories.
Pre erection	Lightning arrester unit Grading rings Surge Monitors	Dimensional verification, Measuring tape, Celofin tape, Calipers Measurement of IR value 2.5 kV Insulation tester for 42 kV LAs and 5 kV megger for LAs above 42 kV. Galvanization thickness on strips using micro tester. Functional check of counter 24 V DC & 7 V rms source multi meter.	Approved drawings IS 2633, IS 6745 Approved GTP, Suppliers test certificate	Item shall be as per approved drawings. Measure and record IR values- Should be > 1 GΩ for 42 kV LAs Should be > 10 GΩ for above 42 kV LAs >65 μ for thickness between 2-5 mm >85 μ for thickness more than 5 mm Should record given pulses Should flicker at 7 V rms Should be <10 V DC	Advise firm in case of mismatch in dimensions and low IR values.
Post commissioning and annual maintenance	Lightning arrester unit	Post commissioning and periodical annual maintenance. 2.5/5.0 kV megger, Leakage current monitor to measure 3rd harmonic resistive leakage current	Records previous measurements of IR value and THRC leakage current value	Cleaning of LA housing Measure IR value and leakage current before and after cleaning of LAs IR values after cleaning should be > 1 GΩ (for 42 kV LAs) and > 10 GΩ (for above 42 kV LAs) Measurement of resistive component of leakage current after cleaning should not indicate any abrupt variation from its previous reading. Further resistive leakage current should be less than 500 μA.	In case of low IR values LA has to be taken out of service and jointly investigate with LA manufacturer. In case of leakage current between 350 – 500 μA, keep it under close observation & beyond 500 μA, remove from service and jointly examine/investigate with LA manufacturer.

Annexure-II

Measurement of resistive leakage current of lightening arrestors

Railway	Division	Name of TSS/GSS	Voltage class of LA	Make & year of manufacturing of LA	Make & Year of manufacturing of equipment used for measurement of resistive leakage current	Voltage at the time of each measurement	I_{total} Total Leakage current (mA)	I_{3t}	I_r