National Electrical Manufacturers Association

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Arrester Condition Monitoring Guide

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Introduction

A vital aspect of asset management on power systems is understanding the remaining life of a critical component. Predicting the life of these components while online or offline is an onerous task at best. This guide offers help when selecting the method to monitor the working condition of surge arresters while in service or recently removed from service in a non-laboratory environment. Condition monitoring of arresters in the field is important on both transmission systems and distribution systems since they are extensively applied in both. The various condition monitoring methods of assessing the life of arresters are reviewed in detail and in summary form in this guide. The positive and negative attributes are discussed for all methods. A summary table that clearly contrasts the benefits of each method based on the situation is presented at the end of the guide.

Energized in Service Test Methods

Thermal Imaging

This form of arrester condition assessment is very fast and effective. Within seconds, an infrared camera can determine if there is a critical arrester condition to be concerned with when entering a substation. If an arrester is in a long-term failure mode and is nearing its end of life, there is a high probability that it will be hot. A hot arrester can be detected from a hundred feet away with even the simplest of infrared detecting equipment.

Comparing arresters on multiple phases of the same circuit is the best way to assess the health of an arrester. Figure 1 is an example of using three similar arresters as a reference to determine if an arrester is running abnormally hot.

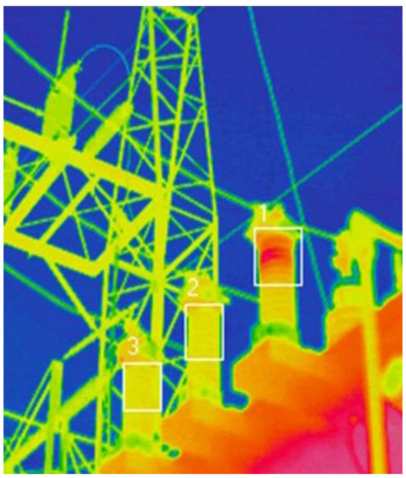

Figure 1 Thermal image of arrester with elevated temperature in comparison to partner arresters on circuit.

Table 1 Suggested actions for arresters with elevated temperatures when compares to partner arresters on same circuit.

Temperature Difference between Units (ºF/ºC)	Suggest Action
0-4/0-2	No action recommended just retest per your normal schedule
5-10/2-5	Retest in 2-4 weeks to determine rate of aging
11-19/6-10	Schedule removal in 1-2 weeks
20-36/11-20	Schedule immediate removal or de-energization
> 36/20	De-energize immediately and do not re-energize arrester with fault current available

In this case, the rightmost arrester is appreciably hotter than the center or left most arrester. Since all the arresters are of the same manufacturer and appear to be of the same design, they should all be close to the same temperature. The only times nearby and similar design arresters within a set should show a temperature variance are:

a. After a surge event
b. After a temporary overvoltage event
c. If the arrester is in failure mode
d. If the arrester is subject to different sun exposure
e. If one of the arresters is near a thermal source on the transformer
f. If one of the arresters is in a shadow

Otherwise, the temperatures should be within 2C of each other. It is quite typical for arresters to run 0-2C above ambient, but any temperature deviations above that should be considered an issue; however, comparison to similar partner arresters is recommended over comparison to ambient. Typically, arresters more than 20C hotter than their partner arresters should be removed immediately because at this temperature, they are soon to fail. As shown in table 1, the difference in temperature between units can be used to guide the next actions.

Even though thermal imaging is a very effective and accurate means of assessing the condition of an arrester at any given time, there are limited models of thermal imaging devices available on the market that can be permanently mounted and situated to measure the temperature of the arrester on a routine basis.

One negative characteristic of this method is that the solar effect on the temperature of an arrester can be significant. Recording a thermal image of an arrester on a sunny day can hide a failing arrester. It is highly recommended that this assessment method be carried out between midnight to 1 hour before sunrise for the most accurate results.

It is also important to ensure that your equipment is not affected by different distances to the arrester when comparing partner units. The resolution of the equipment should also be high enough to discern the arresters, as shown in figure 1.

Thermal Imaging Summary

Sensitivity to Arrester Health:
This method accurately measures the temperature of the device and devices nearby for a relative comparison. Most units can differentiate .5 deg C temperatures which are adequate resolution to compare to other similar nearby energized arresters. However, to ensure the most accurate readout, the reading should be taken during the night after the solar effect has dissipated. The optimum times would be between 12 am through 1 hour prior to sunrise.

Informative:
The output of IR images is abundant with information about the arrester’s temperature but little else. It can tell the user the rough distribution of the temperature. It cannot tell anything about the history before the image. It can tell about the future if subsequent images are taken and compared. The absolute temperature of the arresters is not as important as the difference in temperature between units within a set.

Versatility:
This is a highly versatile test method since it can be used on any type of arrester, any rating of the arrester, and almost any configuration. If used in the presence of sunlight, it reduces the sensitivity of the results.

Speed of Use:
Upon entering a substation, approaching a tower, or approaching a pole, the imaging device is easily switched on, and the output is rapid. Within seconds a thermal image can give the status of the arrester temperatures.

Ease of Use:
Late-model units are quite easy to use but may still require some training or practice.

Remote Sensing:
Since the image is digital, it can be transmitted to different locations using customary broadband methods.

Reliable Predictor of End of Life:
It is generally understood that arresters that are hotter than similar nearby units are likely in a long- or short-term failure mode. However, it is not possible to accurately predict the rate of failure from one image using this monitoring method. Subsequent readings taken over a period of time must be taken to estimate the rate of degradation of the arrester.

Use Energized:
This test method must be completed while the unit is energized. Since this test method uses the temperature (or difference in temperature between similar units) to predict the health of the arrester, it must be energized either by the system or a similar source for several hours prior to the evaluation.

Test While Installed:
This is the preferred state when performing a survey of a set of arresters using this test method.

Test While Uninstalled:

This testing can be done when uninstalled as long as the arrester is energized by a source capable of supplying enough power to heat the unit. However, not having the comparison to other arresters within the set is a detriment.

Recommended Usage Locations:
This method can be highly effective in any location where the arrester can be visually observed. If the arrester is in a cabinet, this method is not nearly as useful. It is also recommended to use this method when the sun is not above the horizon.

This method does not work on externally gapped arresters (EGLA) since there is no way for leakage current to lead to internal or external failure.

Maintenance Cost:
No routine maintenance to the camera is necessary, other than that which is done to normal electronic equipment.

Infrared Thermometer

Do not confuse this method with thermal imaging; this method only offers the user a temperature at the point to which it is aimed. The thermometer must be pointed at several locations on the arrester to assess the full health of the unit. This is an underutilized test method that should be adopted for its safety aspect alone. This type of device can quickly show if an arrester is in a critically hot state and action needs to be taken for safety's sake.

Figure 2 Example of typical infrared thermometer.

The same precautions should be used for this test method as thermal imaging regarding the solar effect. If the reading is taken during full sun, this method may show significant temperature deviations due to a failing arrester with a 5º–10ºC difference in temperature, but a long-term failure with small temperature differences may not be identified.

Infrared thermometers have become a piece of Standard toolbox gear for many electrical workers (see Figure 2) because of their rapid deployment capability and noncontact application method. If an arrester is within the last few months of its life, this test method is most valuable. If the arrester is very hot, above 10º–20ºC hotter than other similar arresters, this device can flag the problem rapidly.

Infrared Thermometer Summary

Sensitivity to Arrester Health**:**

This method accurately measures the temperature of the device and devices nearby for a relative comparison. The accuracy of measuring the health of an arrester is excellent if the measurement is completed at night. Most units can differentiate .5°C temperatures, which is an acceptable resolution to compare to similar nearby energized arresters. If the measurement is done during a sun load, careful analysis is needed before assessing the arrester's health.

Informative**:**

The output is a temperature at the location where the thermometer is pointed. It can tell the user the temperature distribution as the thermometer is pointed at several locations on the sample. It cannot tell anything about the history before the measurement.

Versatility:

This is a highly versatile test method since it can be used on any type of arrester, any rating of the arrester, and almost in any configuration. It can be difficult in the heat of midday when all parts can be affected by solar exposure.

Speed of Use**:**

Upon entering a substation, approaching a tower or pole, the thermometer is easily switched on, and the output is available. Within seconds a temperature on the surface of the arrester can be read.

Ease of Use:

This is the easiest of all arrester test methods. Just point and read.

Reliable Predictor of End of Life:

It is not possible to accurately predict the rate of failure from this type of testing on one occasion. However, if this device is used in separate measurements, a rate of change in temperature can be established, and a rough estimate of time to reach the next temperature level of concern can be ascertained. Note, this applies only in the absence of solar heating, and the temperature difference between partner arresters must be determined.

Use Energized:
This test method must be completed while the unit is energized. Since this method uses the temperature (or difference in temperature between similar units) to predict the health of the arrester, it must be energized either by the system or similar test set for several hours prior to the evaluation. To get the most accurate difference between similar arresters, the reading should be taken after midnight and prior to sunrise.

Test While Installed:
This is the preferred state when performing a survey of a set of arresters using this test method.

Test While Uninstalled:
This testing can be done when uninstalled as long as it is energized by a source capable of supplying enough power to heat the unit to the same level it would see online. However, not having the comparison to other arresters within the set is a major detriment to the sensitivity of the measurement.

Remote Sensing:
These are generally handheld devices, but the data is digital and can be downloaded to other devices, which means it can be remotely read.

Recommended Usage Locations:
This method can be highly effective in any location where the arrester can be visually observed. If the arrester is in a cabinet, this method is not nearly as useful. It is also recommended to use this method when the sun is not above the horizon.

Note: this method cannot be used on externally gapped arresters

Maintenance Cost:
Special maintenance of the instrument is not necessary and can be handled like most electronic equipment.

Partial Discharge Detection

During the life of gapless arresters, the internal components are continually exposed to stresses that can lead to partial discharge (PD) or corona, as it is often called. If PD is present and originates from the external surface of the arrester, it could be harmless to the arrester if the arrester has a porcelain housing. However, if the housing is polymer the external PD can lead to erosion of the rubber and moisture ingress. The erosion can usually be visibly seen if it has gone to the point of moisture ingress. PD generated internally is a reason for concern, as, over a period of time, it may lead to internal tracking and ultimately arrester failure

Figure 3 One example of Partial Discharge Detector

The presence of PD does not necessarily mean there is an issue, nor does it establish the health of the arrester. The uncertainty of the PD location or resulting in damage severity makes this method of assessing the health of an arrester a less reliable method than temperature monitoring or leakage current monitoring.

Most arresters with internal air volume (porcelain housed and hollow-core designs) will experience partial discharge during rain, fog, and sometimes snowy conditions. It is an acceptable condition in most arrester designs for this to occur for short durations and at low levels. However, during dry periods, arresters should not experience internal partial discharge. (Note: There is no well-stablished relationship between PD and the environment outside an arrester. The only time to use this method is during dry weather). Typically, if PD is detected in dry conditions, a manufacturer will recommend removal.

Fortunately for arrester users interested in this type of assessment, it is similar to undesirable conditions in other high voltage equipment. This means the same equipment can be used for more than just arrester assessment. Because this type of assessment equipment is not just a special arrester tool, there is a wider array of online and field-oriented PD detection equipment.

When arresters are manufactured, they must be tested for internal PD. The IEC and IEEE Standards both require that no more than 10 pico-coulombs (pC) be present in the arrester when energized at 1.05 x MCOV. Therefore, 10pC should be the baseline for arrester assessment. If any arrester is exhibiting more than 10pC, then it warrants further monitoring.

The real task in PD detection is filtering the background noise out of the real PD.

Partial Discharge Summary

Sensitivity to Arrester Health**:**
This can be an inaccurate test method since PD does not necessarily imply the end of life is near for an arrester. If the PD originates on an external part of the arrester and is not emanating from an organic part, it is probably harmless and is not an issue in the life of the arrester. However, if the PD is internal to the arrester, the health of the arrester can be diminished.

Informative:
The level of information regarding the status of the life of an arrester from internal or external partial discharge is minimal.

Versatility:
This can be a versatile method of testing arresters. The arrester rating and type do not increase or decrease the amount of PD that may be created. This test can only be done with the power applied to the arrester as it would be on the system.

Speed of Use:
The equipment used to make this measurement is quite sophisticated. It takes training and time to set this equipment up correctly to measure PD in a substation or on lines.

Ease of Use:
Filtering out ambient PD is a major challenge making this test method difficult. Handheld devices can be easier to operate due to built-in filters for background noise.

Reliable Predictor of End of Life**:**
As stated above, this can be an unreliable predictor of the life of an arrester since partial discharge is not always present in a failing arrester, and PD can be present externally, causing no harm to an arrester.

Use Energized:
This test method must be completed while the unit is energized. Partial discharge can only occur when the voltage stress on a point exceeds the electrical strength of the air.

Test While Installed:
This is the preferred state when performing a survey of a set of arresters using this test method.

Test While Uninstalled:
This testing can be done when uninstalled if the arrester is energized by a source capable of supplying enough voltage to reach the MCOV of the arrester.

Remote Sensing**:**
Since the data is digital, this can be transmitted to a remote location.

Recommended Usage Locations:
This method can be where the arrester is visible by the eye. It applies to any arrester where the MOV elements are energized at one end and near ground potential at the other end. Typically externally gapped arresters cannot be tested by this method. Also, arresters that are not energized cannot be tested this way.

Maintenance Cost:
No maintenance is necessary, but the equipment must be handled with care.

Resistive and 3rd Harmonic Leakage Current and Watts Loss

The use of 3rd harmonic leakage current monitors is the method of choice for arrester users interested in continuous long-term condition monitoring of arresters. This method has been developed for the current generation of Metal Oxide Arresters. This method is the most accurate in predicting the life of an arrester and offers the most relevant data about the past and present status of the arrester. IEC Standard 60099-5 has an annex devoted to this type of field testing of arresters. Numerous manufacturers of this equipment are offering many models and capabilities. This leakage current method should not be confused with simple current meters often found on older generation surge counters (see the section on AC Leakage Current Monitors).

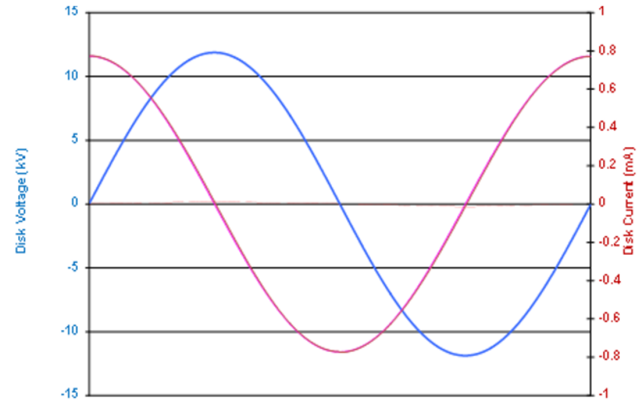

Figure 4 Arrester Voltage and Total Leakage Current

Background

MOV arresters have a complex leakage current that is made up of capacitive and resistive currents. At MCOV, the current is largely capacitive in nature, with very little resistive current flowing. Because of this, special equipment is necessary to discern the two types of current.

Total Leakage Current of an MOV Arrester

Total leakage current is the general term used to describe the current that flows through an arrester at voltages near or below MCOV of the unit. This includes internal and external currents. At these voltages, the current is out of phase with the voltage due to the capacitive nature of metal oxide varistors. Figure 4 shows the leakage current (red) and the voltage (blue) of an 8.4kV MCOV arrester. The peak leakage current is in the range of .8ma at a peak voltage of 12kV. The red current trace lags the voltage trace by 90 degrees. In this example, the leakage current and the total current are synonymous.

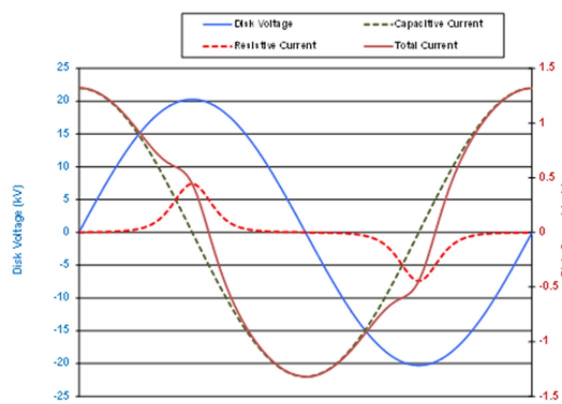

Figure 5 Arrester Voltage and Resistive and capacitive Currents that make up Total current

Resistive Current and Capacitive Current

The resistive current is the current flowing through an arrester that is in phase with the voltage. Technically it is all part of the total current, but it is the current component that is in phase with the voltage that leads to heating and watts loss of the arrester. It is measured by reading the current at peak voltage. Typical resistive current levels at or near operating voltages will be in the 20-200 µA range. At voltages above operating voltage, the resistive current increases nonlinearly relative to the voltage. In figure 5, the resistive current is responsible for the hump in the total leakage current trace. This current cannot be measured with a Standard clamp-on current probe unless the value is processed further by a filter or FFT analyzer. If there is a dielectric breakdown within an arrester, it also manifests itself as a resistive current or current in phase with the voltage. This current is oftentimes temperature sensitive. The higher the temperature in this region of operation, the higher the resistive current.

The capacitive current of an MOV type arrester is the current that flows through the arrester out of phase with the voltage. The capacitive current and applied voltage are related linearly, and this current does not have any real role in the varistor performance. If a true rms current meter is used to measure the current through an arrester, this current dominates the value if measured near and below MCOV. In figure 5, at voltages significantly above MCOV the peak capacitive current is only 1.3mA, where in figure 4, at MCOV the capacitive current is only slightly less at .8mA. This difference demonstrates the insensitivity of capacitive current when the arrester is conducting much more resistive current than it should for a healthy arrester.

3rd Harmonic Current

All currents and voltages are made up of fundamental frequency and sub-harmonic elements. The 3rd harmonic of an MOV arrester current is very closely related to the resistive current of the unit. Because of this close relationship, arrester monitors have been developed that filter out the 3rd harmonic of the total current and use this as a means of predicting the resistive current. There several methods developed to perform these calculations. In particular, a probe is sometimes mounted at the base of the arrester can pick up a signal from the electric field of the arrester that can be used to improve the accuracy of these measurements.

Watts Loss
When using the same current sensors as discussed above, a separate voltage sensor can be added that accurately measures the system voltage. With this information, the watts loss of the arrester can be measured along with the leakage current. This parameter is also very sensitive to the health of the arrester, where even very small changes in watts loss indicate a health issue for the arrester if the measurement is at the same temperature as the earlier one.

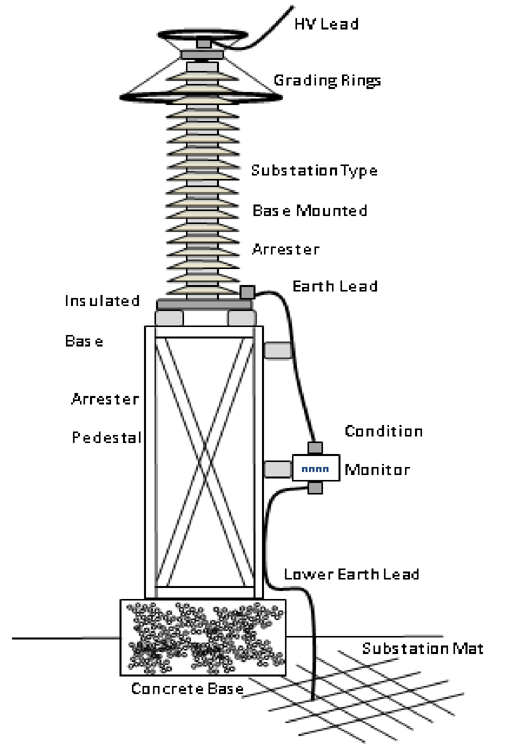

Figure 6 Arrester 3rd Harmonic Monitor Configuration

When using this method of condition monitoring, it is the difference in resistive current or watts loss of partner arresters that offers the most information on the health of the arrester. Both the watts loss or leakage currents should be the same day after day under similar conditions. If either parameter shows a steady increase under the same conditions, then there is likely a long-term issue.

Some of the units available on the market also collect information about the surge history of the unit. Surge counting may be useful for other reasons, but not regarding the health of an arrester.

Resistive and 3rd Harmonic Leakage Current Summary

Sensitivity to Arrester Health:
With the proper equipment, this is a highly accurate means of measuring the present state of an arrester's health. If equipped with memory or cloud storage, it can also provide information necessary to establish changes within the arrester. Arresters that are in short- or long-term (days vs. months) failure mode will exhibit some increase in resistive current long before any other characteristic shows changes.

Informative:
As stated above, the resistive or 3rd harmonic currents are definitive characteristics of an arrester's health. This data coupled with historical data is the best means possible in assessing the health of an arrester.

Versatility:
Using this type of test method must be planned long in advance of its use because the ground end of the arrester must be electrically insulated from ground to make this reading.

Speed of Use:
If the sensors are previously installed, this method is very rapid. If the data is not automatically transmitted to a central point via some method, it can be rapidly collected with special equipment.

Ease of Use:
With the proper training, any line personnel can use this type of equipment. Understanding the output of this type of equipment is not always clear. The main parameter is not the absolute leakage current but any change in the leakage current over time, as well as the difference in leakage current of partner arresters.

Reliable Predictor of End of Life:
This type of measurement is the most reliable means of predicting the end of life of an arrester if historical data is kept on the unit. A long-term change in the resistive current of an arrester is one of the most sensitive characteristics of an arrester's health. Note, there are some versions of this test that can be more sensitive than others see IEC 60099-5 Annex D-2017.

Use Energized:
This type of monitoring should be used while the arrester is energized; however, if the test equipment has memory, the data from this type of transducer can be downloaded even if the arrester is de-energized.

Test While Installed:
This is the preferred state when performing a survey of a set of arresters using this test method.

Test While Uninstalled:
This testing can be done when the arrester is uninstalled as long as it is energized by a source capable of supplying enough voltage to reach the MCOV of the arrester.

Remote Sensing:
Most condition monitors using this method have cloud or local databases connection options for remote monitoring.

Recommended Usage Locations:
This method is well suited to station arrester applications in substations. It can be used on transmission line arresters near substations or locations with easy access to retrieve the data. If the data is sent to the cloud, then the arrangement can be almost anywhere. This application is not typically used on distribution arresters due to the cost. This application will not work for externally gapped line arresters at all.

Maintenance Cost:
No maintenance is necessary, but the equipment must be handled with care.

AC Leakage Current Meter (not 3rd Harmonic Current Measurement)

The AC leakage current meter is a carryover from the gapped silicon carbide arrester era. It is of little value in assessing the health of an MOV-type arrester. By the time current is high enough to register on the mA meters, the arrester fails rapidly thereafter. However, this method could still be used on some models of Silicon Carbide arresters still in service. This type of monitoring can be used to measure the contamination level of the housing insulation in highly contaminated areas.

Note: This is not a recommended condition monitoring method for MOV-type arresters.

Figure 7 AC leakage current meter without 3rd harmonic filtering.

AC Leakage Current Meter Summary (These comments apply to MOV Type arresters only.)

Sensitivity to Arrester Health:
Highly inaccurate in offering information about the health of a functioning MOV arrester. The readout is generally showing the total current, which is dominated by the capacitive current. Capacitive current does not change relative to the health of an MOV-type arrester.

Informative:
No information until very near the end of life.

Versatility:
Non-versatile since it needs installation into the base of the arrester.

Speed of Use:
Fast since it has to be built-in.

Ease of Use:
This equipment is very easy to use.

Reliable Predictor of End of Life:
Not a predictor of anything.

Use Energized:
Provides no output if the arrester is de-energized

Test While Installed:
Can be used while the arrester is installed

Test While Uninstalled:
Cannot be read if the arrester is de-energized

Remote Sensing:
Routinely sensed remotely.

Recommended Usage Locations:
This method is not recommended for any arrester applications under any circumstances.

Maintenance Cost:
No maintenance is necessary, but the equipment must be handled with care.

Surge Counting

This test method is a carryover from the Gapped Silicon Carbide Arrester era. It is of little value in assessing the health of an MOV-type arrester. MOV arresters do not have a limited number of surges before failure.

Surge counters count impulses at currents above certain amplitudes or above certain combinations of current amplitude and duration. If the interval between discharges is very short (less than 50 ms), surge counters may not count every current impulse (and this is quite often the case in multi-stroke flash events). Some counters require power follow current that is generally present through Silicon Carbide arresters 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 overvoltages appearing in the system, or it may provide information on the number of discharges corresponding to significant arrester energy stresses. Please note: Electrical-mechanical surge counters do not provide any specific information about the condition of an MOV type arrester other than it saw a surge above a certain amplitude. Sometimes knowing if a surge has been present on a system is important, and a surge counter is quite valuable for that application. But since only surges of very high magnitude or very long magnitude can degrade an MOV type arrester, the number of surges is not an indicator of the health of an arrester. Arresters can withstand thousands of surges as long as the surges are within the operating capability of the arrester.

Installation Considerations: For a surge counter to operate properly, the arrester must be isolated from earth with insulators at the base and the counter electrically mounted in series (see figure 6 in Resistive and 3rd Harmonic Leakage Current). The surge counter should be located where it can be read from ground level with the arrester in service. The installation should be done without considerably lengthening the earth connection or reducing its cross-section. It is important to note that the insulators need to have strength high enough not to reduce the specified cantilever strength of the arrester.

Note: This is not a recommended condition monitoring method for MOV-type arresters.

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Surge Counting Summary
Sensitivity to Arrester Health:
Highly inaccurate in offering information about the health of a functioning arrester.

Informative:
No information regarding the life expectancy

Versatility:
Non-versatile since it needs installation into the base of the arrester.

Speed of Use:
Fast once it is installed in the arrester base.

Ease of Use:
This equipment is very easy to use.

Reliable Predictor of End of Life:
Not an end of life predictor of a functioning arrester.

Use Energized:
Can be read if the arrester is de-energized

Test While Installed:
Can be used while the arrester is installed

Test While Uninstalled:
Can be read if the arrester is de-energized

Remote Sensing:
Routinely sensed remotely.

Energized out of Service Test Methods

Reference Voltage with Hipot Tester

Every MOV type arrester has a voltage current characteristic (VI), similar to what is shown in Figure 8. During steady-state operation, an arrester operates at levels well below the start of heavy conduction (>1mA). The basis of this test method is to force conduction of the arrester up to approximately 1-10 mA (DC or Peak or RMS) and then record the voltage at that point. The voltage across the arrester that results in 1-10 mA conduction through the arrester is often called the reference voltage of the arrester. This point on the VI characteristic curve is very consistent from arrester to arrester of the same manufacturer and vintage over a wide temperature range. Table 2 can be referenced for the range of 1-10 mA voltages to be expected for various arresters. When running this test, the turn-on voltage is compared between similar arresters. If there is more than a few percent difference when compared to similar arresters, there is probably an arrester health issue.

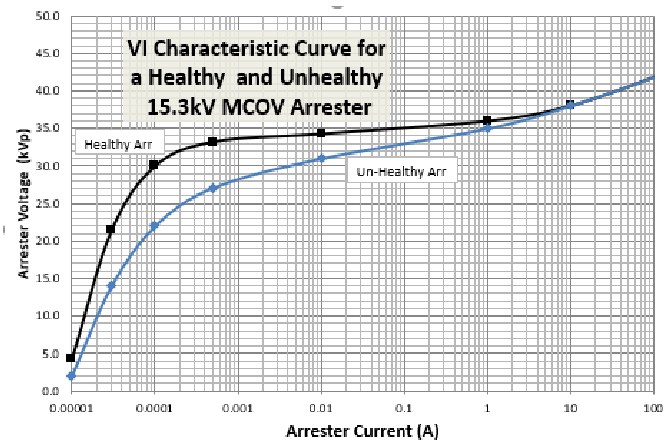

Figure 8 Simulation of a VI Characteristic Curve for a good and defective arrester.

Typical Current and Voltage Values for HiPot Testing of Arresters

Arrester MCOV or Uc	Target AC Test Voltage	Minimum AC Voltage at 1 mA (kV RMS)	Typical Maximum AC 1 mA voltage (kV RMS)	Suggested AC HiPot Tester Rating (kV RMS)	Target DC Test Voltage	Minimum DC Voltage at 1 mA (kV)	Typical Maximum DC 1 mA voltage (kV)	Suggested DC HiPot Tester Rating (kV)
2.55	4.55	4.33	4.78	5kV	6.38	6.06	6.69	10kV
8.4	15.0	14.3	15.8	20kV	21.0	20.0	22.1	25kV
10.2	18.2	17.3	19.1	20kV	25.5	24.2	26.8	30kV
12.7	22.7	21.5	23.8	25kV	31.8	30.2	33.3	50kV
15.3	27.3	26.0	28.7	30kV	38.3	36.3	40.2	50kV
19.5	34.8	33.1	36.6	40kV	48.8	46.3	51.2	75kV
22	39.3	37.3	41.3	50kV	55.0	52.3	57.8	75kV
29	51.8	49.2	54.4	75kV	72.5	68.9	76.1	100kV
42	75.0	71.3	78.8	100kV	105	100	110	125kV
84	150	143	158	200kV	210	200	221	250kV
98	175	166	184	200kV	245	233	257	300kV

Table 2 Typical Test Value (Note voltages can be higher or lower, however a group should all be very close to the same level.)

While this test method does not appear in any IEC or IEEE Standard/Application guide, it has been used for more than 30 years by arrester designers and manufacturers. This test method is only applicable to non-gapped MOV-type arresters. It cannot be used on gapped silicon carbide arresters or, in general, on arresters with a manufacturing date before 1980.

AC or DC Hipot testers can be used to perform this test in the field.

Reference Voltage with Hipot Tester Summary

Sensitivity to Arrester Health:
The turn-on voltage or reference voltage of an arrester is an extremely sensitive characteristic related to the health of an arrester. A typical hipot tester can be used and show a 1-2 percent difference in turn-on voltage.

Informative:
The only information measured on this test is the voltage level at which an arrester starts to conduct. If several similar arresters are measured, this is enough information to ascertain the health of the arrester.

Versatility:
Because of the availability of a hipot tester, this can be a very versatile test method.

Speed of Use:
If performing this test in the field, the arrester needs to be removed or at least disconnected at one end. This makes the speed of this test slow. The actual test with a hipot tester is in the 1-minute range.

Ease of Use:
If a portable tester is being used for this test and the arrester is already uninstalled, this is an easy test to perform. If the arrester is tested in place, wiring can be difficult.

Reliable Predictor of End of Life:
This method of condition monitoring can tell the user if the arrester has an issue as compared to a partner arrester. However, there is no way to predict the time to end of life using this test method one time.

Use Energized:
The arrester must be de-energized from the system and then is energized by another source where current and voltage can be metered.

Test While Installed:
This test method requires at least partial removal from the circuit.

Test While Uninstalled:
This is the preferred method.

Recommended Usage Locations:
This method can be used on any ungapped MOV type arrester. Note, this is not an online measure of health.

Remote Sensing:
Not likely.

Watts Loss at 5kV or 10kV

This is a popular means of testing arresters that have been uninstalled. It achieves its popularity because the equipment used for measuring the health of insulators is readily available at larger utilities. However, it is only useful if previous data under similar ambient conditions has been collected on the same arrester or similar models of arresters. Measuring watts loss at voltages well below its MCOV yields nearly no useful data on an arrester if only measured one time.

Note: This is not a recommended condition monitoring method for MOV type arresters.

Watts Loss at 5kV or 10kV Summary

Sensitivity to Arrester Health:
Measuring watts loss of an arrester well below its MCOV does not yield useful information about the arrester if measured only one time. However, if the measurement has been repeated many times over a long period, then it is possible to assess the health of the arrester, albeit fairly insensitive

Informative:
The information is relatively un-useful without previously collected data to compare with. However, if a large sample set of similar models are tested, this data can be informative.

Versatility:
This type of test equipment is quite versatile and often used for measuring tan delta (losses) of insulators.

Speed of Use:
This is a time-consuming method since the arresters need to be disconnected from the circuit at a minimum.

Ease of Use:
This type of equipment is not difficult to use, but training is necessary.

Reliable Predictor of End of Life:
This is a good end-of-life predictor if the unit has a long history of data collected on it. For a single reading, it cannot predict the health or time to end of life.

Use Energized:
The equipment must be energized by the tester alone and not the system voltage.

Test While Installed:
Can only be tested if partially or fully uninstalled.

Test While Uninstalled:
This testing can be done when uninstalled.

Remote Sensing:
Not likely since the arrester needs partial un-installation.

Recommended Usage Locations:
This method of condition monitoring is not recommended for any arrester type or location.

Maintenance Cost:
No maintenance is necessary, but the equipment must be handled with care.

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Ohmic or Resistance Measurement

The use of an ohmmeter or megohmmeter (megger) is only a means of determining if an arrester is shorted or open. It cannot tell anything else about the health of the tested arrester. This is not a recommended test method by most arrester manufacturers for assessing anything other than a failure, which is usually visible, eliminating the need for further testing.

Note: This is not a recommended condition monitoring method for MOV-type arresters.

Ohmic or Resistance Measurement Summary

Sensitivity to Arrester Health:
Highly inaccurate in offering information about the health of a functioning arrester. It can be used to determine if the arrester is a short and failed.

Informative:
This test method can only tell if the arrester is a short or open. It cannot determine the health of a functioning arrester.

Versatility:
Very versatile but does require that at least one end of the arrester be uninstalled.

Speed of Use:
This is a time-consuming method since the arresters need to be disconnected from the circuit at a minimum. Once it is disconnected, measuring resistance is quite fast, albeit an irrelevant measurement.

Ease of Use:
This equipment is very easy to use.

Reliable Predictor of End of Life:
Can effectively tell if the arrester has failed, but not a health predictor of a functioning arrester.

Use Energized:
Cannot be used while the arrester is energized.

Test While Installed:
Can only be tested if partially or fully uninstalled.

Test While Uninstalled:
This testing can be done when uninstalled.

Remote Sensing:
Not likely since the arrester needs partial un-installation.

Recommended Usage Locations:
This method of monitoring the health of an arrester is not recommended for any locations or applications.

Maintenance Cost:
No maintenance is necessary, but the equipment must be handled with care.

Arrester Sparkover

This is a carryover from the gapped silicon carbide arrester era. It is of little value in assessing the health of an un-gapped MOV type arrester but can be used for a gapped MOV arrester. If it is used on a gapped silicon carbide arrester, it can offer limited information about the arrester. A hipot tester can be used to make this assessment. The sparkover level of a gapped MOV arrester is typically 1.5 to 2 times the MCOV of the arrester.

Note: This is not a recommended condition monitoring method for MOV type arresters unless they contain a series Gap.

Arrester Sparkover Summary

Sensitivity to Arrester Health:
Can be an accurate means of assessing the turn-on voltage of a gapped arrester. If its sparkover has changed significantly, it may be in danger of failing. It is best to test several arresters to compare the results.

Informative:
Sparkover level information is partially indicative of the health of a gapped arrester. A larger sample set is best.

Versatility:
Not versatile since the arrester must be uninstalled to use.

Speed of Use:
Fast once the arrester is uninstalled.

Ease of Use:
If a hipot tester is used with training, the equipment is very easy to use.

Reliable Predictor of End of Life:
Cannot predict the end of life but can determine if the arrester is different than others and considered for removal.

Use Energized:
Cannot be used if the arrester is energized

Test While Installed:
Cannot be used while the arrester is installed

Test While Uninstalled:
This is the preferred state of the arrester when tested with this method.

Remote Sensing:
Not likely

Recommended Usage Locations:
Only for internally or externally gapped MOV arresters.

Conclusion

Although there are many methods available for assessing the health of an arrester, some are more informative than others. While some are easier to use than others, some are only valid for gapped MOV arresters or SiC arresters, and others are only applicable for MOV arresters. This paper is intended to give users an overview of all the available condition monitoring methods to help in the selection of the one that meets the specific need of the arrester in question and the available equipment. It is recommended that the user review table 3, the arrester condition monitoring method comparisons table, for a quick comparison of the available arrester condition monitoring options.

Arrester Condition Monitoring Method Comparisons

Definition of Terms	Sensitivity to Arrester Health	Informative	Versatility	Speed of use	Ease of use	Reliable Predictor of Life	Initial Cost	Maintenance Cost	Use energized	Test while installed	Test while Un-installed	Remote Sensing
Thermal Imaging	High	High	High	Fast	Easy	Can be High	Medium	Low	Yes	Yes	No	Can be
Infrared Thermometer	High	Can Be High	High	Fast	Very Easy	High	Very Low	Low	Yes	Yes	No	Can be
Partial Discharge Detection	Low	Low	Medium	Slow	Difficult	Low	High	Low	Yes	Yes	No	No
Resistive or 3rd Harmonic Leakage Current	Very High	High	High	Slow	Difficult	Can be High	High	Low	Yes	Yes	Can be	Yes
Leakage Current on 1-30 ma Scale	Very Low	Very Low	Low	Fast	Easy	Very Low	Low	Low	Yes	Yes	No	Yes
Surge Counting	Very Low	Low	Low	Fast	Easy	Very Low	Low	Low	Yes	Yes	No	Yes
Reference Voltage with Hipot Tester	High	High	Low	Slow	Easy	Can be High	High	Low	No	No	Yes	No
Watts Loss @ <50% Uc or MCOV	Very Low	Very Low	High	Slow	Easy	Can be Good	Medium	Low	No	No	Yes	No
Sparkover	Very Low	Low	Low	Slow	Medium	Very Low	Medium	Low	No	No	Yes	No
Ohmic	Very Low	Very Low	High	Fast	Easy	Very Low	Low	Low	No	No	Yes	No

Table 3 Arrester condition monitoring method comparisons

Definition of Terms Used in The Analysis of Test Methods

Sensitivity to Arrester Health:
Sensitivity refers to how accurately the specific measurement type assesses the health of the unit. A healthy unit would be as it operated when initially installed.

Informative:
When testing an arrester, many characteristics can be measured, Watts, Temperature, Difference in Watts at different voltages, 3rd harmonic currents, how all the aforementioned characteristics have changed recently, max temperature, min temp in the last selected time period.

Versatility:
A most versatile test method would be where the same tester could be used for all voltage ratings without setup changes. A least versatile tester method would be when significant setup was required when changing the type or rating of arrester to be tested. Also, movement from one location to another is part of the versatility.

Speed of Use:
How quickly is there an output regarding the health of an arrester once it is desired?

Ease of Use:
Does this type of test require an advanced degree in testing techniques, or can anyone use and understand?

Reliable Predictor of End of Life:
This attribute is about predicting the probability of a failure.

Test while installed:
Can this test be performed when the arrester is still installed in the circuit? Energized or not.

Test when Uninstalled:
Does the arrester need to be disconnected from the circuit when being tested?

Tested when Energized:
Verifies if the arrester needs to be electrically energized for this particular test to be valuable.

Remote Sensing:
Can this test result be transmitted to a remote site for monitoring?

Recommended Usage Locations:
This section offers guidance to where specific types of monitoring can or cannot be used.

Maintenance Cost:
If this applies, how much does it cost to keep the equipment in good operating condition?

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