

SURGE ARRESTERS AND TESTING

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Surge arresters are often “overlooked” when performing Power Factor tests on transformers, breakers and other apparatus in a substation. Often times, the testers are aware of how a transformer or a breaker functions, but are not aware of the intended purpose of the surge arresters. Since there are no “moving” parts to maintain or an oil sample to pull, it is often their policy not to perform any testing of the arrester.

Surge arresters are devices that help prevent damage to apparatus due to high voltages. The arrester provides a low-impedance path to ground for the current from a lightning strike or transient voltage and then restores to a normal operating conditions. A surge arrester may be compared to a relief valve on a boiler or hot water heater. It will release high pressure until a normal operating condition is reached. When the pressure is returned to normal, the safety valve is ready for the next operation. When a high voltage (greater than the normal line voltage) exists on the line, the arrester immediately furnishes a path to ground and thus limits and drains off the excess voltage. The arrester must provide this relief and then prevent any further flow of current to ground. The arrester has two functions, it must provide a point in the circuit at which an over-voltage pulse can pass to ground and second, to prevent any follow-up current from flowing to ground.

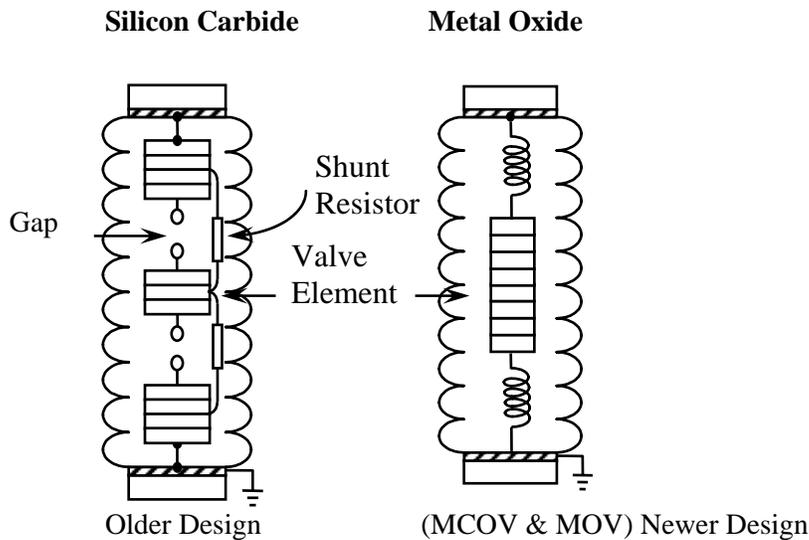
The technology of surge arresters has undergone major changes in the last 100 years. In the early 1900's, spark gaps were used to suppress over voltages. In the 1930's, the silicon carbide replaced the spark gaps. In the mid 1970's, zinc oxide gapless arresters, which possessed superior protection characteristics, replaced the silicon carbide arrester.

A great number of silicone carbide arresters are still in service. The silicone carbide arrester has some unusual electrical characteristics. It has a very high resistance to low voltage, but a very low resistance to high-voltage. When lightning strikes or a transient voltage occurs on the system, there is a sudden rise in voltage and current. The silicone carbide resistance breaks down allowing the current to be conducted to ground. After the surge has passed, the resistance of the silicone carbide blocks increases allowing normal operation. The silicone carbide arrester uses nonlinear resistors made of bonded silicone carbide placed in series with gaps. The function of the gaps is to isolate the resistors from the normal steady-state system voltage. One major drawback is the gaps require elaborate design to ensure consistent spark-over level and positive clearing (resealing) after a surge passes. It should be recognized that over a period of operations that melted particles of copper might form which could lead to a reduction of the breakdown voltage due to the pinpoint effect. Over a period of time, the arrester gap will break down at small over voltages or even at normal operating voltages. Extreme care should be taken on arresters that have failed but the over pressure relief valve did not operate. This pressure may cause the arrester to shatter.

This design is not as popular due to the emergence of the Metal Oxide Varistor (MOV) arrester. Silicon carbide arresters are vulnerable to moisture ingress that leads to failure due to reduction in spark over. Contamination can also upset voltage distribution resulting in spark over reduction. Over a period of time, excessive energy inputs can destroy the ability of the blocks and gaps to interrupt follow current leading to failure of the arrester. In an October 1996 issue of the IEEE Transaction on Power Delivery, Dr. M Darveniza recommended that all silicon carbide arresters that have been in service for over 13 years be replaced due to moisture ingress. His tests revealed that degradation was evident in 75% of arresters tested.

To determine if a silicon carbide arrester warrants replacement, field-testing must be performed. The ideal method is to determine the protective level of the arrester, this is not practical since an impulse generator is required. An effective and more practical method is to determine the watts-loss of the arrester and compare to like arresters. Testing methods will be reviewed later.

The MOV arrester is the arrester usually installed today. Doble documentation reveals that MOV type arresters entered the market in the United States around 1976. The metal oxide arresters are without gaps, unlike the SIC arrester. This “gap-less” design eliminates the high heat associated with the arcing discharges. The MOV arrester has two-voltage rating: duty cycle and maximum continuous operating voltage, unlike the silicone carbide that just has the duty cycle rating. A metal-oxide surge arrester utilizing zinc-oxide blocks provides the best performance, as surge voltage conduction starts and stops promptly at a precise voltage level, thereby improving system protection. Failure is reduced, as there is no air gap contamination possibility; but there is always a small value of leakage current present at operating frequency.



It is important for the test personnel to be aware that when a metal oxide arrester is disconnected from an energized line a small amount of static charge can be retained by the arrester. As a safety precaution, the tester should install a temporary ground to discharge any stored energy.

Duty cycle rating: The silicon carbide and MOV arrester have a duty cycle rating in KV, which is determined by duty cycle testing. Duty cycle testing of an arrester is performed by subjecting an arrester to an AC rms voltage equal to its rating for 24 minutes. During which the arrester must be able to withstand lightning surges at 1-minute intervals. For station class arresters, the magnitude of this surge is 10kA (10,000 Amperes). For intermediate and distribution class arresters, this surge is 5 kA (5000 Amperes). The surge wave shape is an 8/20, which means the current wave reaches a crest in 8 milliseconds and diminishes to half the crest value in 20 milliseconds.

Maximum continuous operating voltage rating – MCOV. The MCOV rating is usually 80 to 90% of the duty cycle rating.

ANSI/IEEE C62.1 (IEEE Standard for Gapped-Carbon Surge Arresters for AC Power Circuits) and C62.11 (IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits) separates lightning arresters into four classes: station, intermediate, distribution, and secondary.

As one may guess, each class offers different levels of protection and energy diversion. The station class arrester offers the best level of protection and is capable of diverting the most energy. The intermediate class has the next best level; with a lower energy diversion capability than the station class arrester. The distribution class arrester offers the lowest level of protection with the lowest energy diversion capability. The secondary class arrester does not overlap with any of the other classes that makes it difficult to compare with the other classes. The station class arresters offers the most protection, but the higher protection also results in higher costs per unit.

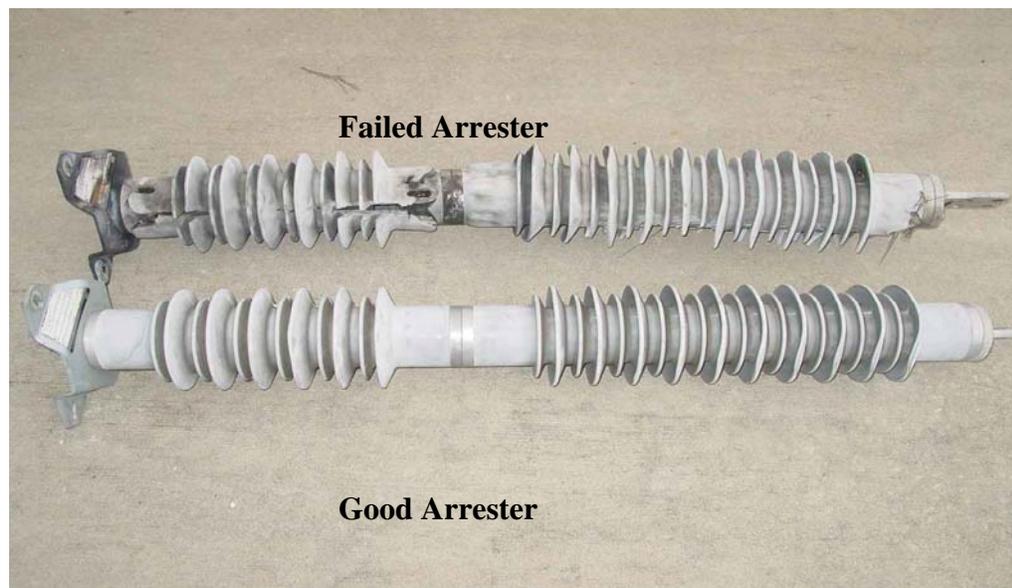
Polymer/Porcelain Arresters:

Polymer arresters are gaining in popularity over the porcelain arresters. When a reclose operation occurs and the fault has not cleared, the arrester is subjected to a second fault current. This second operation often leads to arrester explosion since the porcelain had already been weakened by the first fault. If the pressure relief rating of the arrester is exceeded, the arrester may fail violently, since it cannot vent the excess gasses. This type of failure can lead to other equipment being damaged or injury to personnel who may be in the vicinity of the failure. Due to the ability of the polymer station arrester to vent out the side, the housing is not weakened when exposed to the fault current. Therefore a polymer arrester can be reclosed on multiple times without the fear of a violent failure. The polymer arresters are less expensive than the porcelain arrester and appear to avoid some of the in service problems, such as moisture ingress, that often occur in porcelain arrester. One manufacturer reports that moisture ingress is the direct cause of failure in 86% of all failures.

Handling Suspect Arresters:

- A damaged seal-gapped arrester should be handled with care. Due to increased pressure caused by the destruction of internal elements, a defective arrester may become an explosive hazard.
- If the decision is made to perform an internal inspection of the failed arrester, be assured that the arrester has vented properly
- Do not “throw away” a defective arrester – the arrester should be properly vented before disposing

Polymer Arrester Failure



Note that the arrester is basically intact. The side slit, but no pieces are blown away from center.

Polymer Arrester split, but still intact



As mentioned earlier, one of the hazards of a silicon carbide arrester not venting properly can result in an explosion of the device. The failure of the arrester and the expulsion of the porcelain can result in damage to other apparatus due to shrapnel from the arrester. Several times bushings have been damaged, not by the fault, but by shrapnel from the failed arrester.

Porcelain Arrester Failure



Top Arrester is Intact
(Note pieces of porcelain on ground)

Base of Failed Arrester

Combining Different Arresters:

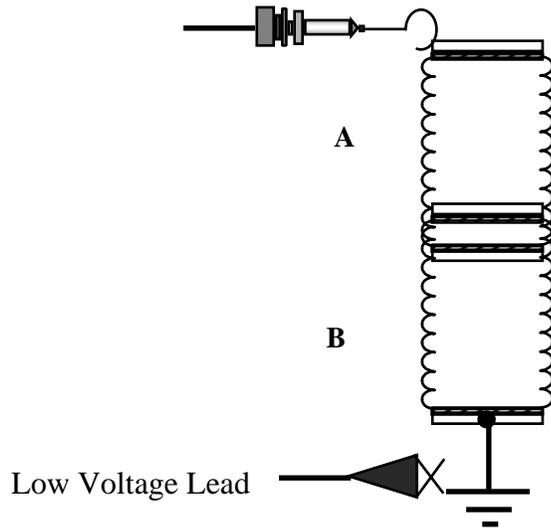
Mixing of silicon carbide and metal oxide arresters is not normally recommended, but with proper application they can be combined. If all arresters on one phase of a three-phase system are MOV type arresters the other two phases may continue to use the silicon carbide type arresters. Energy rating should be considered when replacement occurs. Mixing arresters on the high and low sides of the same phase may cause problems if not properly applied. Usually there is no problem having a MOV arrester on the high side with an silicon carbide on the low side. An MOV arrester should not be placed on the low side of a transformer if the high side is protected by a silicon carbide, due to the concept of a transferred surge. An arrester that appears as the lowest impedance will take the bulk of the energy of the surge. The switching surge from the low side may be transferred to the low side arrester, due to the high spark over voltage of the silicon carbide arrester. The low side arrester (MOV) may fail due to the fact that it cannot handle the high duty. This idea of the silicon carbide arrester having a higher spark over voltage than the discharge voltage of the MOV arrester also applies to the use of station class entrance arresters. The transformer mounted MOV arrester may take the surge since the silicon carbide has the higher spark over voltage. Having the silicon carbide arrester at the entrance does no harm unless the fails and then the issue of reliability becomes a concern.

Testing:

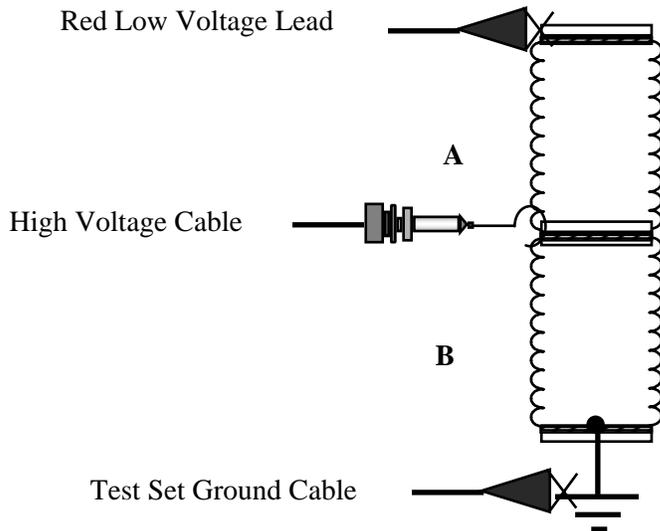
Two of the most common tests to perform in the field on surge arresters are the Doble Power Factor test and infrared analysis. Some manufacturers state that no single test will indicate the complete operating characteristics of the arrester. Reference service advisories from some manufacturers recommend Power Factor testing and infrared as a method to detect possible problems caused by moisture ingress. Field-testing of arresters by Power Factor, infrared, or other methods is used as a reference. Different models and makes of arresters will have different watts-loss readings. The tester is attempting to identify a variance in the past watts-loss readings. Power Factor is not calculated since the current is so small. The arrester should have a visual inspection to detect cracks in the porcelain, abnormal rust staining, and any abnormal physical condition of the arrester that is observed. Incorrect factory installation of arrester gaskets has been detected by visual inspection upon receipt of the arresters.

When performing Power Factor testing, each unit should be tested as a separate unit. A test performed on more than one arrester either in series or parallel will diminish the effectiveness of the tests. This masking effect can become more of a problem if a larger arrester is paired with a smaller arrester in a single stack. If the smaller arrester were to increase in watts-loss, the overall effect of the stack could be minimal or go unnoticed. If a two stack arrester had one unit with higher than normal losses and the other unit with lower than normal losses, they could cancel the difference in watts-loss.

**Incorrect Method for Two Stack Arresters:
Arresters A & B are being measured**



**Correct Method for Two Stack Arresters:
Arresters A & B are being measured**



Arresters A and B must be measured one at a time as follows:

To Measure:	Select This Circuit:
A	UST Measure Red
B	GST – Guard Red

In this example, the Red Low Voltage Lead was used. The Blue Low Voltage Lead could have been used, in which the tester would select the blue for the circuit. Use the multiple test choice to speed the procedure.

Arrester Test Results Analysis:

- Refer to published tabulations
- Compare current and watt-losses obtained for identical units tested under same conditions
- Any deviation, either higher or lower, should be investigated
- Compare to previous tests, if available
- Ratings are based on watts-Loss values and not % Power Factor Calculated
- No correction factor for arresters
- If necessary, contact your Doble engineer

Analysis of Abnormal Losses:

Silicon Carbide Arresters:

Higher than Normal Losses

- Contamination by Moisture, Dirt or Dust
- Corroded Gaps

Lower than Normal Losses

- Broken Shunting Resistors
- Poor contact and Open Circuits Between elements

Changes in Current

- Mechanical Damage

Metal Oxide

Higher than Normal Losses

- Contaminated by Moisture, Dirt or Dust
- Corroded Gaps in early Design (newer designs are gapless)

Lower than Normal Losses

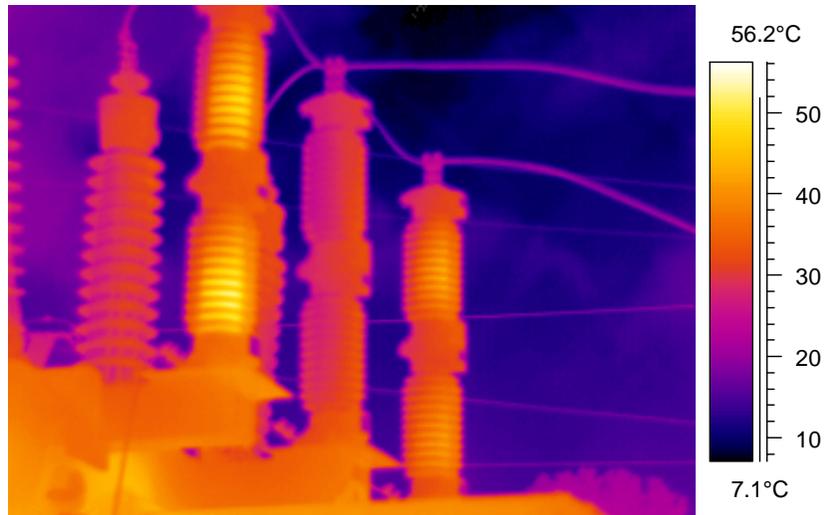
- Discontinuities in Internal Electrical Configuration

Acceptance testing should be performed on all new arresters in order to compare to other like arresters and for future benchmarking. Incorrect assembly at the factory or shipping damage may allow moisture ingress of the “just received” arresters. Higher than normal losses could be moisture, with lower than normal losses may be due to physically damaged internal components caused by incorrect handling during shipment or installation.

Routing tests should be performed on the arrester after placing into service. It is ideal if this test could be within the first year of operation (warranty), but with today’s maintenance practices the first opportunity to retest the arrester could be five to seven years. Current and watts-loss measurements should be compared to the initial tests. Any changes in current and watts-loss should be noted and investigated.

Infrared analysis of the arrester is gaining in popularity and has been used by several companies with good results in identifying higher than normal current flow through the metal oxide components. Routine

testing on a normal basis is recommended in hopes of identifying and replacing defective arresters before equipment damage or personal injury.



115 kV Arrester 10° Centigrade above Ambient

CONCLUSION

As mentioned, normal testing that is performed in the field will not precisely assess the characteristics of the arrester. Power Factor testing comparing watt-loss has proven to be one of the most reliable methods of determining any physical changes and changes that are results of contamination or deterioration. Infrared analysis of arresters is gaining in popularity as the arresters are scanned with the rest of the substation apparatus. One advantage for performing an IR scan is that the apparatus is not removed from normal operating service. Routine testing on a normal basis is recommended in hopes of identifying and replacing defective arresters before equipment damage or personal injury.

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