ArresterWorks

Arrester Condition Monitors

A State of the Art Review

4/23/2012

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On Line Arrester Condition Monitoring and Off Line Arrester Field Testing
A State of the Art Overview

Introduction

As the demand for more reliable electric service continues to rise, the demand to reduce outages through better system monitoring raises with it. Since arresters are surge protective devices and they mitigate the effect of potential outage causing events, they are often considered when considering ways to reducing outages. For a vast majority of its life, an arrester behaves as an insulator with low levels of leakage current over the insulating surface and very low levels of leakage current through the zinc oxide disk material. Monitoring this leakage current is an important step that can be taken to understand the health of the arrester.

Various assessment methods and indicators for revealing signs of deterioration or indications of possible failure of the arrester have been utilized for as long as arresters have been in use. The assessment methods range from fault indicators and disconnectors, which indicate complete arrester failure, to instruments that are able to measure small changes in the resistive leakage current and/ or power loss of gapless metal-oxide arresters.

The aim of this document is to provide guidance to those interested in assessment methods. The methods considered are thermal electrical and mechanical. It also gives detailed information about leakage current measurements on metal-oxide arresters.

Also considered in this document are assessment methods carried out when the arrester is off line or in the lab.

Figure 1 Surge Counter mounted on an arrester pedestal

Definitions

Arrester Condition Monitoring: is generally considered to be on line and continuous

Arrester Field Testing: is generally off line and done a few times during the life of an arrester.

Purpose of Monitoring and Field Testing

Asset management is a growing concern in a leaner business environment. A popular form of asset management is to use a condition based maintenance program. This type of asset management doesn't require a specific schedule, but rather a more efficient condition based

schedule. For this type of maintenance program to work, however the condition of the asset must be known and monitored. Determining the condition of an arrester asset is still a developing field and several methods are currently available. Because condition assessment is not a low cost endeavor arrester condition monitoring is most often performed only at critical locations where an arrester failure could cause serious ramifications in the form of an outage and loss of revenue. In these cases it is generally the goal to predict eminent arrester failure and have it removed before it does indeed fail.
Arrester Field Testing, another form of asset management, is carried out most of the time to determine if an arrester should be or could be reinstalled safely.

Types of Monitors
Surge Counters:
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. Repetitive surges do not degrade MOV type arresters.

Figure 2 Typical Surge Counter Face with Analog Leakage Meter and electro/mechanical counter

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. 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.

AC Leakage Current Meter: AC leakage meters are generally an accessory of surge counters. When the readout is an analog meter, the current being read is the total current of the arrester. The total leakage current of the arrester is a combination of the capacitive current and resistive current through the disks and over the external housing of the arrester. If the arrester

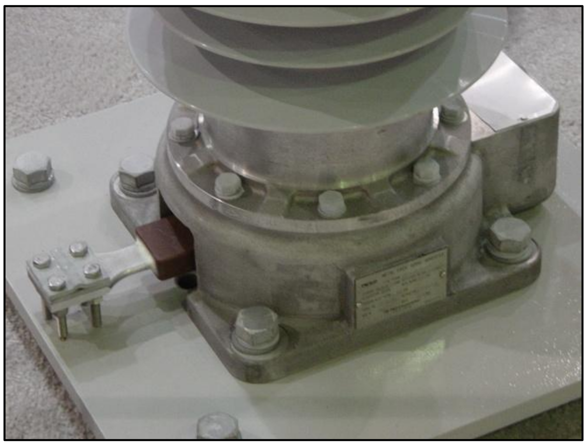

Figure 3 Arrester with special ground connection for internal leakage current measurement

is equipped with a special ground terminal that isolates the internal from external currents, then just the total internal current can be monitors without the interference of the external surface leakage current. Another advantage of this arrangement as shown in figure 3 is that no insulators are needed on the bottom of the arrester if monitoring the external surface leakage current is not necessary. For very tall and/or arresters in a high seismic region this could be quite an advantage.

Because metal oxide disks are more like insulators than conductors during steady state, they conduct very little resistive current. However they can carry 2-10 ma of capacitive current. This high level of capacitive current offers no real data about the condition of an arrester. If an arrester is failing, the current on the leakage current meter may or may not change at all.

Unfortunately a 5 ma or higher total current (99% capacitive) shrouds the resistive current and eliminates any real detection of the resistive current which is the current that is a true indicator of the condition of the arrester. Note in figures 4 and 5, the total current trace is very similar between the two and the watts loss have doubled. The rms current value of the two traces would be a fraction different and not indicating any real issue, however if the arrester had doubled its watts loss (resistive current) a utility would immediately check it out. Therefore there is no real information about the condition of an arrester if an analog ac meter is used. If the resistive current becomes high enough to affect the current reading and become visible on an analog meter, it is in a rapid failure mode and it is unlikely that that it will be in this state long enough to be detected by an inspection.

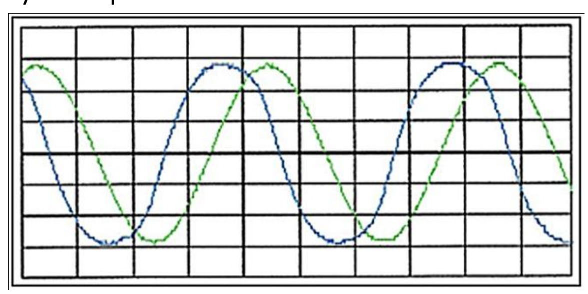

Figure 4 Blue Total Current leading the Green Voltage on a substation type arrester dissipating 18 watts

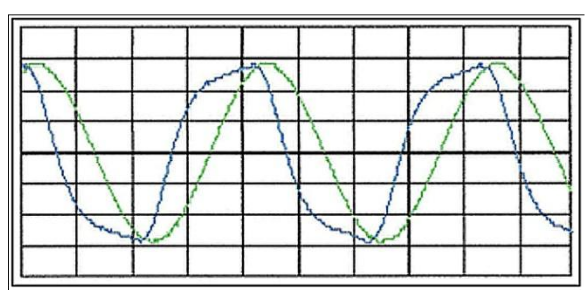

Figure 5 Blue Total Current on substation type arrester dissipating 40 watts at nearly the same rms current as in figure 4.

Third Harmonic Current Measurement

More recent vintage and design surge counters with third harmonic current sensing offer significantly more information on the condition of the arrester than earlier generations of surge counters that were designed for SiC arresters. The model offered by ABB in figure 6 is a multi functional arrester condition assessment tool. It not only counts surges down to 10 amps, but it also time stamps them and holds the data in its memory until the data is down loaded by a remote control unit. The surge amplitude and time are recorded along with leakage current data. From the total current the device calculates the third harmonic of the current.

Figure 6 A recent vintage third harmonic condition monitor by ABB.

This third harmonic value is a very close representation of the resistive current. From the third harmonic current the condition of the arrester can be very accurately assessed. If the current has increased by only a few percent, it is detected and stored in the local database.

The data is stored until an operator downloads it through the hand held device. One handheld device can be used for many sensors.

The first on line arrester condition assessment device that used the third harmonic current as its fundamental means of assessment was from a company called TransiNor. Asle Schei was the inventor of this system of assessment in the mid 1980's. His company and invention was acquired by Doble Engineering who presently offers a high quality diagnostic tool based on the original device introduced by TransiNor.

Figure 5 A recent vintage on-line diagnostic tool for measuring resistive current in an arrester

Doble's LCM II offers the user the ability to measure and store data for up to 1000 arresters. It also is capable of continuous online surveillance of any arrester with the use of modem communications to a PC.

A third option in the recent vintage assessment tools is the Arrester Condition Monitor (ACM) manufactured by Siemens. The ACM offers both local readout and remote continuous readout of the arrester condition. According to Siemens the device spends its first day determining the arrester characteristics and uses that data to evaluate its condition on future days. This diagnostic tool also appears to be the only device on the market that is IEC 61850 ready. This means that in the future, when fully integrated station condition monitoring systems are in common use, this assessment tool will not require any major modification to be included in the system.

Figure 6 Siemens ACM (Arrester Condition Monitor) with advanced communications capabilities and 3rd harmonic evaluation of leakage current

Partial Discharge Detection:

During the life of gapless arresters, the internal components are continually exposed to stresses that can lead to partial discharge. 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. However during dry periods, arresters should not experience partial discharge. Partial discharge within an arrester can lead to dialect failure of insulating materials. Because internal partial discharge (PD) in an arrester is an undesirable condition, detection systems have been developed to locate internal PD and give arrester users the ability to proactively mitigate the issue. Fortunately for arrester users interested in this type of assessment it is very 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 too, there is a wider array of on line 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. 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. There are a few products on the market that can do this. Doble produces a very portable unit that has an excellent graphic output that is able to discriminate between background and the real signal.

Figure 7 Doble Handheld Partial Discharge Detector

Thermal Imaging:

This form of arrester condition assessment is a very fast and effective. Within seconds, an infrared detector can determined 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 meters away with even the simplest of infrared detecting equipment. Figure 10 is an example of using three similar arresters as a reference to determine if an arrester is running abnormally hot. In this case, the center arrester is about 9C hotter than the left most arrester. Since all the arresters are of the same manufacturer and it appear to be of the same design, they should all be the same temperature. The only time nearby and similar design arresters should be of different temperature is after a surge event or temporary overvoltage event. Otherwise the temperatures should be the same. It is quite typical for arresters to run 0-5C above ambient, but any temperature deviations above that should be considered an issue. This author has never seen an arrester more than 20C hotter than ambient other than in the lab.

A 10C difference between two arrester of the same design and vintage is considered a take action level. What is meant by “take action” is that the activities to remove the arrester from the energized circuit should be initiated. Between 5 and 10C the arrester should be watched. If the arrester is in a critical circuit, then it is advisable to also start the removal process. If an arrester is 15C different or higher than other similar arresters, then it should be de-energized as soon as possible to avoid an outage. If the arrester is a porcelain housed arrester, and the temperatures are 15C or higher then personnel should not be near the arrester until it is de-energized for safety sake.

Figure 8 Substation Class Arresters with one unit about 9 C higher than the coolest unit

Figure 9 Distribution Arrester with 15C difference between hottest spot and cooler part of the arrester

Even though thermal imaging is a very effective and accurate means of assessing the condition of an arrester there is no 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 last comment on this method of arrester condition assessment and that is one does not need a multi functional thermal imaging device to detect if the temperature of an arrester is abnormal. There are many hand held infrared thermometers that can measure the temperate of a spot. The device in figure 12 costs less than 200 dollars and within a moments time can measure the temperature of an arrester from as far away as one likes.

Figure 10 Infrared Thermometer A cost effective means of assessing the temperature of an arrester.

Off Line Arrester Field Testing

Off line field testing of arrester is required if an arrester has been removed from its service location or if it is still in the circuit but has been de-energized for some time. The methods and ease of testing arresters to determine if they are worthy of re-installation is much more onerous than on line monitoring. If at all possible, arresters should be assessed while on line. The main issue with off line testing is that to effectively assess an arrester condition it must be energized near or above its operating voltage. For medium voltage arresters this is not so difficult, but for a 100kV or greater rated arrester it is difficult to produce the necessary voltages. The voltage can be AC or DC, but whichever it is, if it is not at or above an arrester's MCOV there is very limited data to make a good assessment.

The optimum off line field test is to apply an AC voltage to the arrester and measure the leakage current. As with the on line monitors, the only leakage current that matters is the resistive leakage current. The total current that is predominately capacitive is not a good indicator of an arresters condition. Therefore any equipment used must be able to discern the total current from the resistive current.

There is no such stand along off line test equipment for arrester above 10kV that this author is aware of. Any equipment that measures watts losses of an arrester below the arrester Uc rating can only marginally predict the condition of the arrester. If there is a large population of arresters to assess, this method can be more effective, but still not optimal.

An alternative to the optimum piece of test equipment is to use a standard Hipot tester. Again this can only be accomplished if the arrester Uc rating is below the maximum voltage of the hipot tester. If an AC hipot tester is used, the best the most effective means of assessing the arresters condition is to determine at what voltage the arrester starts heavy conduction. This is also referred to as measuring the arrester Vref. Vref is a term used to quantify the level where an arrester conducts 1-5 ma of resistive current. The method is to energize the arrester until it conducts approximately 1mA. If this level is 5-15% above the Uc rating then the arrester is most likely a good arrester. Fortunately in a substation if an arrester is off line it usually has two partners. All three arresters should be tested. In this case, all three arresters should have the same turn on point and if not the one with the lower value should perhaps be evaluated back at the lab.

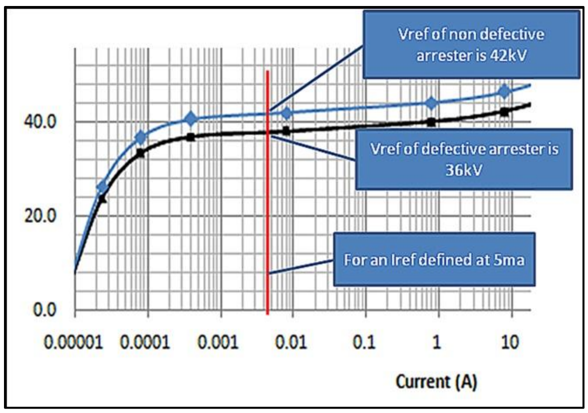

Figure 11 Example of how to Vref Test an Arrester with a Hipot tester

Summary

In summary, there is very few options for field testing a de-energized arrester. If it is necessary, then Vref testing is an effective means.

Arrester condition assessment is still a developing area with many options available and may more opportunities ahead of us. As the smart grid concept evolves, these assessment tools will become mandatory and not just for critical areas. This overview of the state of the art is by no means a total summary of all the equipment available, but just a sampling. In 10 years I predict a completely new line of devices will be available for this important task.

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