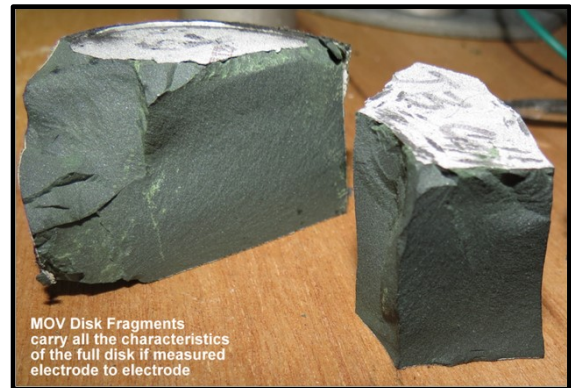
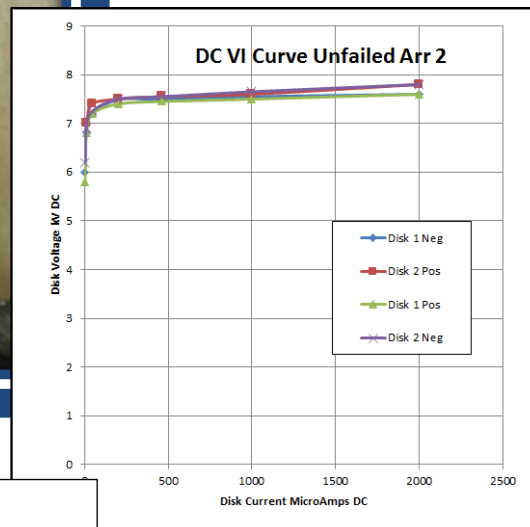


ArresterWorks

Example Arrester Forensic Analysis



MOV Disk Fragments carry all the characteristics of the full disk if measured electrode to electrode



Note this is in no way a critique of any particular supplier. All arresters can be overloaded (or as some call it, failed). In this case the supplier offered an excellent arrester that was subjected to a TOV event above the design limit of the arrester

Background

This analysis covers one set of three arresters from the circuit supporting *****. The arresters were located in a transformer enclosure. They were at the end of a short circuit that included three single phase fuses installed temporarily until a recloser can be installed. For unknown reason the fuse on phase C opened and remained open until crews re-fused sometime later. Upon re-energization of the system the arrester on the C phase along with each of the fuses on all three phases operated.

Arrester Description

Intermediate Arresters (3 Units)

39 kV rms Rated Gray Polymer Arresters with 31.5 MCOV kV rms. Fault Current Capability: 16.1 kA rms, Energy rating of 3.6kJ/kV MCOV and cantilever strength of 3,000 inch-pounds.

Two units had experienced external flashover with no other outward evidence of internal failure and the third arrester on phase C had ruptured. All disks were intact in the ruptured arrester. Arresters were removed during the spring 2014. All three were manufactured in 2013.

Physical Analysis

Failed Arrester

The failed unit (Fig 1) had experienced significant fault current during the final failure event which ruptured the rubber at that point.. The unit did not shatter which is by design. All disks were still in the unit. Both the top and bottom seal were in good condition and did not appear to be broken.



Figure 1 – failed arrester 21353008506



Figure 2 - Failed arrester 21353008506 with housing removed

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Review of internal components showed that all disks had carbon on the sides. One disk showed significant external damage (Fig 3) and three had evidence of external tracking (Fig 5). It was evident that the arrester had experienced a long term low current overvoltage resulting in the depolymerization of the fiberglass wrap (Fig 4).



Figure 3 - Carbon and melted aluminum as a result of flashover.



Figure 4 - Depolymerization of fiberglass wrap

Figure 5 - Carbon on disks from failed arrester 21353008506. Red line traces tracking on side of disks.



Additional photos of Failed Arrester



Figure 6 – Top stud of failed arrester



Figure 7 – Main expulsion point of failed arrester module



Figure 8

Electrical Analysis of Failed Arrester

To test the disks of the failed arrester they were fragmented to eliminate any influence from the carbonized sides (See Annex A for more information on this technique). The VI characteristics of the fragments represent the VI characteristic of the full disk.

Because the disks positive and negative characteristic curves are very similar we know that there was no extra high lightning surge to these arresters. (Figure 9)

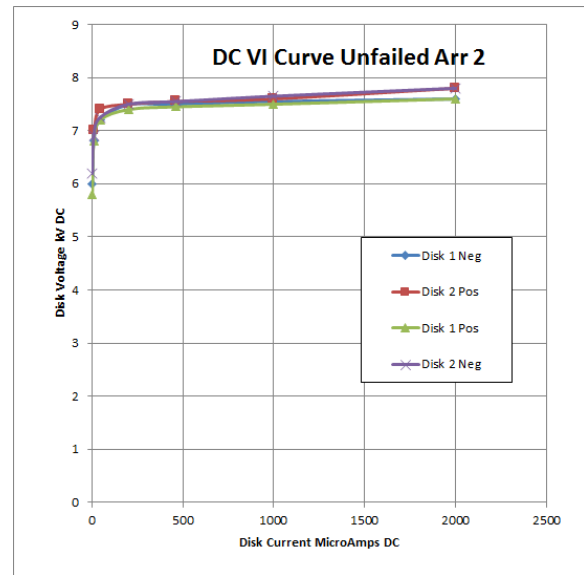


Figure 9 - VI Curve of disk from failed arrester

Partner Arresters

The two (2) partner arresters showed some signs of burning and arc marks on the top studs and name plates (Fig 12), which is believed to be collateral flashover from the failed arrester. There was considerable arc damage to the top of arrester 21353008505 resulting in the seal to be compromised (Figure 10), the bottom seal was intact. Both the top and bottom seals of arrester 21353008504 were intact. Removal of the housing from the partner unit 2153008505 showed that the internal module was in like new condition (Fig 13) with silicone grease filling all the interstices of the filament wrap. The housing was not removed from arrester 21353008504 although it showed minor burn marks on the housing (Fig 12) there was minimal arc damage (Fig 11) and both the top and bottom seals are intact.

Conclusion form Physical Examination

Based on the condition of the fiberglass wrap (depolymerized) and the events as described by Perry, arrester 2153008506 failed due to a long term low current overvoltage that occurred while the system was single phasing, and it would have not been visible outwardly. When the failed arrester was energized a second time the arrester internally flashed over, faulted to ground and ruptured. Single Phasing on Wye-Delta circuits is explained in more detail in Annex B.



Figure 10 – Arc marks resulting from flashover on arrester 21353008505. Arrow points to area of compromised seal.



Figure 11 – Arc marks on top stud of arrester 2135008504.



Figure 1 – Burn marks resulting from flashover on arresters 21353008504 (left) and 2153008505 (right).



Figure 13 – Internal module of arrester 2153008505.

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Final Conclusions

The failure of arrester 21353008506 was due to a 60 Hz overvoltage. The overvoltage occurred in two parts:

1. The first occurred when the fuse blew and only two fuses were still engaged for some extended period of time. During that period, the arrester experienced a low current overvoltage on the phase that was open via a backfeed through the transformer primary of the unfailed phases to the secondary and then back to the transformer primary of the open phase. During this period it burned the epoxy/fiberglass coating around the MOV disks and leaving only the glass strands and failed disks. The current in this type of overvoltage is quite low (mA to a few amps) and often times the arrester does not look failed as you experienced.
2. When the open phase was refused, the arrester was already 100% failed but not rupture because there had not been enough energy flowing to blow the housing off. When C phase was refused, the fault current through the arrester caused enough gas to be generated within the arrester for it to rupture.

This failure scenario is evident by the highly burned epoxy/fiberglass coating under the rubber of the arrester and the sequence of events as described by Perry.

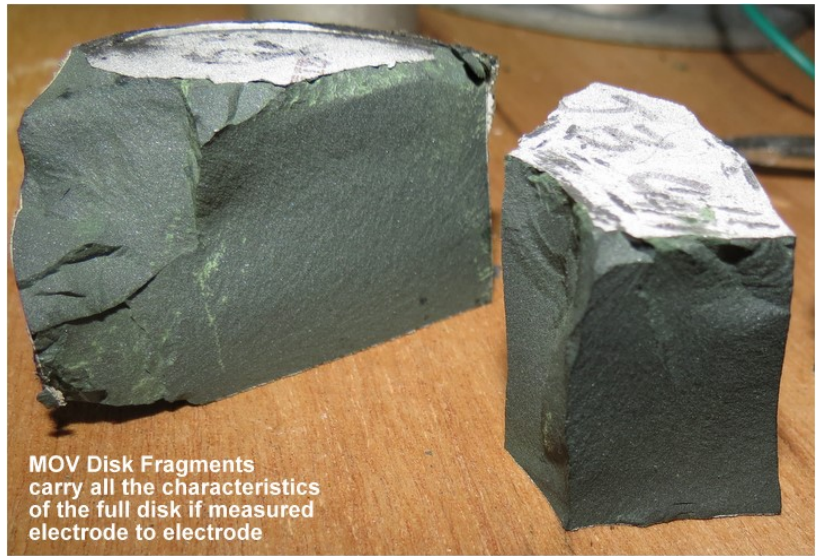
Recommendations

The arrester is the right rating for the system if there is a fault on one phase, but it is not sufficient when the circuit experiences single phasing. If all three fuses had operated, this failure would not have happened. For this reason the overcurrent device needs to be a three phase device, not single phase fuses or cutouts.

Annex A

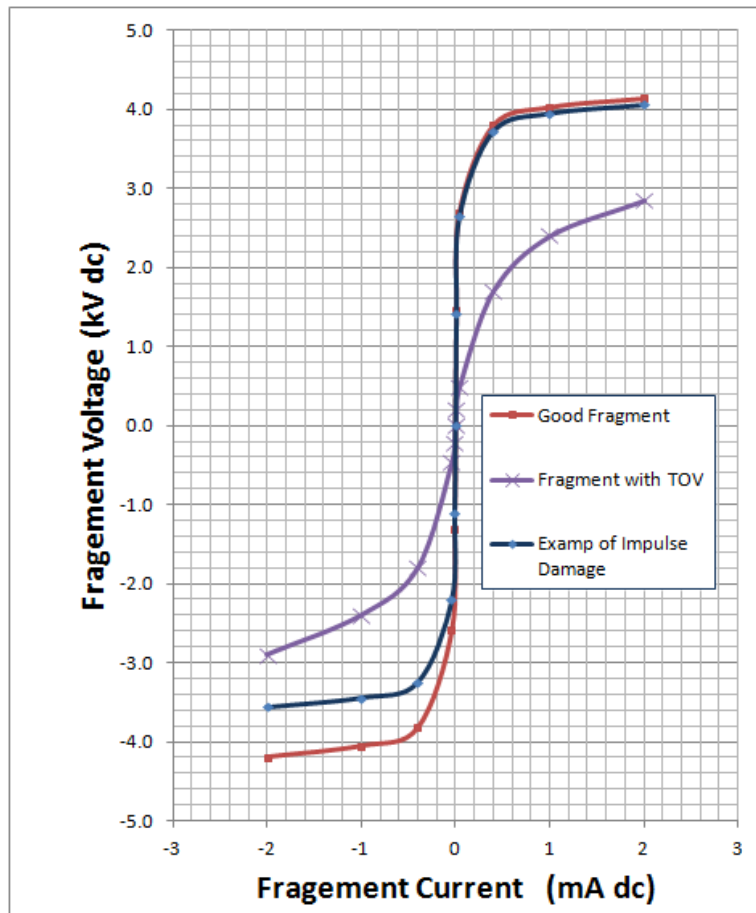
Disk Fragmenting

Disk Fragments are parts of a MOV disk that has been broken out of the center of the disk. By fragmenting a disk, any failed sections of the disk can be removed leaving side surfaces that are not conductive. The fragments show a VI characteristic very similar to the complete disk. Since the fragment has a smaller cross section, the absolute VI values may not be the same, but it is close enough to be considered the same. Watts loss will of course be different.



VI Characteristic Curves

1. The Good Curve has symmetrical Pos and Neg Characteristics. Also the knee of the curve is very pronounced.
2. The Impulse Damaged Curve shows Asymmetry in its VI Curve. The positive knee is higher than the negative knee. The knee is still pronounced.
3. Fragment that has experienced a high temperature TOV event shows less non linearity and



Annex B

Common Arrester Failure Scenario

Single Phasing on Wye/Delta circuits

If B and C are energized and A is open, the voltage at A can float as high as Phase to Phase voltage (of 37.3 kV in this case) due to backfeed from the secondary on the transformer. Any voltage above 31.5kV at A' in this case (MCOV of the arresters) will put the A phase arrester in conduction. Because it is a backfeed situation, the available current at that point is very low (few amps or less) and it just raises the temperature on the arrester until it burns up. Sometimes it only burns the fiberglass structure internally, but sometimes can turn the rubber housing into a molten mess too.

