Abstract – Energy co-ordination of surge arresters

This is a topic which is regularly overlooked and probably the most common cause for failure of surge arresters.

Many people believe that the more surge arresters you install the better the level of protection obtained. This is all very well if viewed purely from a voltage protection perspective but can lead to premature failure of surge arresters. Cascading of surge arresters based purely on voltage protection levels without fully understanding energy co-ordination is a recipe for disaster.

Many suppliers of surge arresters tend to sell their products purely on surge handling ability (kA), reaction time and clamping voltage. Obviously the surge arrester that reacts the fastest is the first to operate and hence takes most of the energy. In many cases this can lead to low energy, fast reacting surge arresters being overstressed causing damage to equipment.

In light of the above problem SANS 10142-1:2009 section L.1.3.3, which states “When more than one SPD is connected on the same conductor, coordination between them shall be ensured.” Many manufacturers and sellers of surge arresters have no idea as to how their surge arresters will react when cascaded with each other.

This problem is further aggravated when different surge arresters from different manufacturers are installed in an installation.

Introduction

When selecting surge arresters most people only think of the surge handling ability or kA rating, clamping voltage or residual voltage and the reaction time

Obviously these are important factors but there are many more factors that need to be considered as well. One which is required in terms of SANS 10142-1:2009, which is a legal requirement, is energy co-ordination.

There is no easy way to ensure energy co-ordination and hence one has to rely on a reputable manufacturer who would have conducted tests and done the calculations to ensure that the surge arresters will comply.
Body

Due to the fact that the concept of energy co-ordination is difficult to comprehend the easiest way to demonstrate the problem is by doing simulated testing.

If one installs surge arresters and looks at the rated clamping voltage only it is very simple to cascade surge arresters. Obviously the lowest voltage would react first and the highest voltage would react last.

To simplify matters if we choose surge arresters all with the same rated clamping voltage, typically 275V and install them with a few meters of decoupling conductors between them, say 10 meters (Figure 1). Theoretically this would ensure that the first surge arrester took the majority of the surge and the subsequent surge arresters would take any residual that gets through. This would further be improved due to the fact that the additional cable between the surge arresters would introduce inductive de-coupling between the individual arresters.

All of the above hold true when exposed to induced surges of (8/20) wave shape as the energy is relatively low and distributes evenly over all the surge arresters. This means that typically you could use a 80mm disc, followed by a 40mm disc and then lastly a 20mm disc all decoupled by 10 meters of cable.

![Figure 1](image)

Unfortunately the co-ordination of surge arresters is not as simple when we look at energy co-ordination when exposed to direct lightning surge currents of (10/350).
Many manufacturers are now making single units which meet the criteria of Type 1 and Type 2 in a single unit, making it much easier to install surge arresters. This means that you install a single surge arrester to meet the protection requirements but unfortunately you may forget about the surge protection installed inside the equipment (Figure 2).

When surge arresters are tested for compliance with the requirements for Type 1 they are only subjected to a test impulse of wave shape (8/20) and the residual voltages are obtained from this test (Figure 3).
This is not the same as a direct lightning surge current which is (10/350) wave shape and has at least 20 times the energy, and this is where the problem arises.

So to see what happens when the same surge arrester is exposed to direct lightning surge current of (10/350) and the effects on a downstream surge arrester, laboratory tests were conducted (Figure 4).

The test circuit was as follows.

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### Figure 4

A combination **Type 1** and **Type 2 metal oxide varistor surge arrester** (SPD) was used in conjunction with a **S20K275** metal oxide varistor using an impulse of 12.5kA (10/350) (Figure 5). The test was repeated increasing the spacing between the 2 x surge arresters from 500mm to 10 meters to see the effects. The longer the cable between the 2 x surge arresters the better the chances of co-ordination.
In both test, the S20K275 downstream surge arrester, normally installed internal to the equipment, was destroyed (Figures 6 & 7). This proves that it is nearly impossible to co-ordinate upstream metal oxide varistor type surge arresters with low energy downstream surge arrester.

The test was then repeated using combination Type 1 and Type 2 spark gap type surge arrester (SPD) in conjunction with a S20K275 metal oxide varistor using an impulse of 12.5kA (10/350) (Figure 8). The test was repeated increasing the spacing between the 2 x surge arresters from 500mm to 10 meters to see the effects.

In both test, the S20K275 downstream surge arrester, normally installed internal to the equipment, survived.

This proves that it is possible to co-ordinate upstream spark gap type surge arresters with low energy downstream surge arrester.
The reason that the **Type 1** and **Type 2** spark gap type surge arrester (SPD) in conjunction with a S20K275 metal oxide varistor using an impulse of 12.5kA (10/350) is energy co-ordinated is as follows.

The **Let Through Energy** of the Spark Gap is far less than that of an equivalent Metal Oxide surge arrester. The reaction curve of a Spark Gap (Figure 9) is very different to that of a Metal Oxide surge arrester (Figure 10). This results in no more current flowing through the terminal equipment varistor, once the spark gap has triggered.

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**Figure 9**

**Figure 10**

The difference between a co-ordinated solution and which is not is clear to see from the comparative testing (Figure 11)

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**Figure 11**

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<table>
<thead>
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<th>Comparison of the co-ordination behaviour of a spark gap and a varistor</th>
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⇒ "Reduction of the impulse time"
References
1.0 SANS 10142:2009
2.0 Energy coordination of SPDs in accordance with EN 61643-12 (VDE 0675-6-12): September 2010
   Annex J: Coordination of SPDs and relevant test methods
3.0 Measurement of the voltage protection level (acc. to EN 61643-11)
4.0 Dehn & Söhne Germany