A SHIELDED SURGE ARRESTER TO PROTECT EXPENSIVE MEDIUM VOLTAGE EQUIPMENT SUCH AS TRANSFORMERS AND SWITCHGEARS

Frank Claeys, Rufei Long
Euromold, Nexans – Belgium, Nexans - Shanghai
Frank.claeys@nexans.com

ABSTRACT

The use of surge arresters in overhead lines as protection for distribution lines is well known. Modern products exist of metal oxide blocks installed in a silicon housing with sheds. A lot of publications are available on these products. Shielded surge arresters installed in parallel with a rubber connector directly on the equipment are less known. This article is about a surge arrester in an EPDM housing. It describes the construction details and the testing procedures. The result is a very compact product in line with modern cable connecting systems that give an optimal protection of expensive equipment.

1. INTRODUCTION

Surge arresters protect distribution lines overvoltages.

There are many causes for overvoltage's such as: lightning strikes, short circuits, earthing faults, operations of circuit breakers disconnecting switches, harmonic waves, resonances… The most severe overvoltage in distribution lines are caused by lightnings.

The acceptable level of the overvoltage by lightning strikes is determined by the insulation class of the network. Pole arresters, terminations, distances to earth potential, are determined in such a way that when the insulation level of network is exceeded, flashovers are initiated and only a part of the overvoltage flows in the network. The actual lightning can have a voltage of some millions volt.

In the past different types of surge arresters were used:

- Conical spark gaps
- Silicium-Carbid Surge arrester (SiC- surge arrester) with spark gaps and resistance
- Metal-Oxid-Surge arrester (MO-surge arrester) without spark gaps (is today mainly used for the protection of totally enclosed SF6- equipment in connector form).

This third type of surge arrester is the subject of this paper.

Shielded Nexans surge arrester(right) attached to connector (left)

Non-shielded ABB surge arrester

Fig. 1: Overhead surge arresters versus shielded surge arresters. (source: Nexans Network Solutions NV – Div Euromold / ABB)

2. THE CHARACTERISTICS OF A MO-SURGE ARRESTER

A surge arrester does not have spark gaps. It can absorb current pulses and limit voltage peaks. In undisturbed use it is high insulating. When a certain voltage level is reached, in µs- time it becomes conductive and limits the voltage to a predetermined value. In the conductive condition there is a residual voltage between the clamps of the surge arrester and the earth that is lower than the insulation level of the network. When the overvoltage is reduced, the surge arrester will then again become insulative in µs- time. For the switching there is no need for a zero voltage transfer which is the best suitable for low usage frequencies such as 16⅔Hz, trains and DC systems. A surge arrester is not designed to limit AC frequencies.

Surge arresters are categorised according to the standardized nominal derivation currents. The nominal impulse leakage current is the peak value (e.g. 5 kA, 10 kA, 20 kA, ...) for which the surge arrester is loaded for 8/20 µs during the type test [1]. At this value the residual voltage at the arrester is defined.

For medium voltage in general 5 and 10 kA surge arresters are used. 10 kA surge arresters are used in equipments that are connected to the overhead line for a relative short distance. With longer cable lengths also 5 kA arresters can be used, since the derivation current reduces with the length of the cable. Also for pure cable systems, where the surge arresters have the only task to limit the overvoltages, 5 kA arresters are completely sufficient.

Fundamentally the type tests of a 5 kA, and a 10 kA surge arrester are different. A 10 kA surge arrester has to absorb more energy than 5 kA surge arrester. The energy is converted at the arrester in heat and this cannot be too high for a thermal stability. The power absorption ability is mainly determined by the surface of the ‘metal oxide tablets’. One can say that the larger the diameter of the tablets, the more energy can be absorbed by the arrester.

‘Tablets’ are manufactured with diameters between 30mm (medium voltage) up to 70mm (high voltage and extra high voltage) for production reasons. Their height varies (voltage-dependent) between 20 and 45mm.

Fig. 2: ZnO tablet

The residual voltages amounts for example for a surge voltage of 10 kA (8/20µs) with a ‚tablet’ with a diameter of 30mm to 450 V per mm overall height and for a ‘tablet’ with a diameter of 7 mm to 280 V per mm height. Depending on the required voltage X pieces of ‘tablets’ are hooked up in series in surge arresters between the high voltage potential and the earthing.

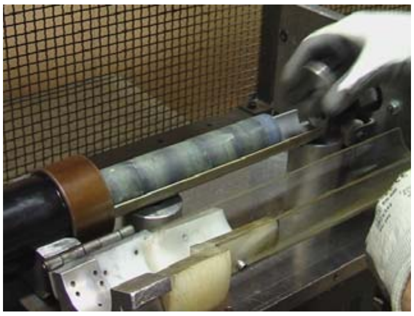

Fig. 3: A stack of ZnO tablets

The tablets have a typical non-linear voltage-current characteristic, as given in figure 4. This ’e is shows a varistor effect.

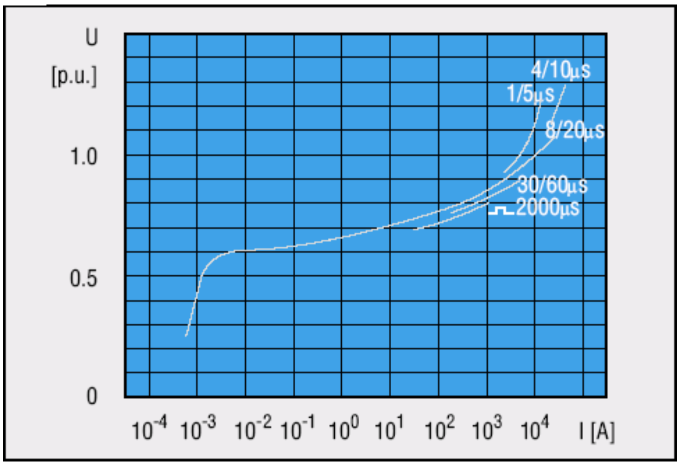

Fig. 4: SA-VI Charachteristics (source: ABB* [2] *)

3. USE OF SURGE ARRESTERS

Surge arresters are used to protect equipment (switches, transformers, cables, accessories…). They have the task to limit the voltage peaks above the basic insulation level. At lightning impulses the most extreme over voltage demands (impulse voltage) arise in the medium voltage net. Example: Equipment (switches, transformers, cables, accessories..) are in a 10 kV Net assigned for min. 75 kV impulse voltage, in a 20 kV Net for min. 125 kV impulse voltage and in a 30 kV Net for min. 170 kV impulse voltage. As overvoltages arise e.g.

during thunderstorms, the maximum occurring voltage peak can be at least smaller than a factor 1/1,15 of the insulation voltage of the net. That is in a 20 kV Net (Isolation level 125 kV) 109 kV. When surge arresters are used in such a net, the maximum remaining residual voltage at the arrester clamps, phase against earth, will be minimum a factor 1/1,4 smaller then the insulation level of the net. In a 20 kV Net this is about 89 kV. This ‘margin’ is meaningful, since the residual voltage, depending on the cable length between the surge arrester and the equipments which can be protected, increases again by reflections.

During the determination of the overvoltage protection, it is absolutely to be noted that a surge arrester can only protect a limited range. In a medium voltage net this is only some meters.

Example: Protection of a cable from the overhead line transition to the switchgear. Here in principle a surge arrester is necessary at the connection point overhead line/cable (at the pylon).
At the other end of the cable a surge arrester is further recommended, if a length between the pylon feet and the cable end of about 30 m in a 10 kV Net, 25 m in a 20 kV and around 20 m in a 30 kV net has to be exceeded.

Shielded surge arresters are installed directly on the equipments (transformer, switchgear) so that we don’t have to worry about protection lengths.

4. CALCULATION OF SURGE ARRESTERS

In the following example calculations the surge arrester is determined for a stable continuous operation. If one demands a higher protection level, this can influence the stability of the surge arrester negatively. The higher the protection level, the higher the surge arrester is thermally loaded, due to the derivation current (µA- range).

Low impedance or rigidly grounded net:

Minimal requirements are:

$U_c \geq 1{,}05 \cdot U_m / \sqrt{3}$
$U_r = 1{,}25 \cdot U_c$

If there are no special requirements of the maximum working voltage levels, applies:

$U_c = 1{,}4 \cdot U_m / \sqrt{3}$
$U_r = 1{,}25 \cdot U_c$, is the result not dividable by 3, it has to be rounded towards the next number that is dividable by 3. [1]

If data concerning the net condition are available (overvoltage heights, interruption times ..), different values can be used, which offer a possibly higher protection level.

Compensated or high impedance net: (usually in Germany)

For an arrester between phase and earth:
$U_c = U_m$

For an arrester between transformer neutral and earth.
$U_c = U_m / \sqrt{3}$

$U_r = 1{,}25 \cdot U_c$ is the result not dividable by 3, it has to be rounded towards the next number that is dividable by 3. [1]

5. CONSTRUCTION

In the Euromold type of surge arrester the zinc oxide blocks are pressed with compressed air in a rubber housing.

This rubber housing is specially designed to be coupled with a rubber connector, avoiding electrical problems at the so called ‘radial air gap’ at the connection of the semi conductive layer of the surge arrester to the semi conductive layer of the rubber connector (figure 6). This coupling is studied with electrostatic field calculation programs.

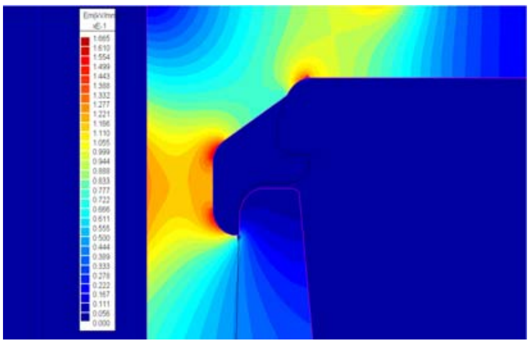

Fig. 6: The electrical stress at the radial air gap.

The 3 mm thick conductive jacket of the surge arrester (as the rubber connector) assures the stability of this semi conductive layer also when immersed in water and when attacked by gasses (as ozon).

All the housings are tested for partial discharges and AC withstand at the prescribed voltages.

After the assembly of the ZnO blocks in the housing, the complete product is retested for partial discharges at the prescribed voltage. After that, the routine tests as described in the standard IEC such as IEC 60099-1are done.

Fig.7: A 51 kV surge arrester during the routine test.

6. TYPE TESTS FOR THE CHINESE MARKET

In 2007 Euromold extended the product range of its surge arrester surge for 42 kV networks, as used in China. These surge arresters passed the type test in the laboratories at a specialised laboratory at Wuhan in China.

The following tests were done:

On the blocks :
- Residual voltage test:
  - Steep current impulse
  - Lightning impulse
  - Switching impulse
-Long-duration current impulse Withstand test
-Operating duty test

On the complete surge arrestors :
-1mA DC reference voltage:$U_{DC.1mA}$
- Leakage current @ 0.75$U_{DC.1mA}$
- Long-duration current @ Uc
-1mA AC reference voltage$U_{AC.1mA}$
- Internal partial discharge test
- Sealing test
- Bending moment
- Insulation withstand test on the arrester housing

The tests are reported in the following test reports. In 2008 the 51 kV surge arrester is introduced in the market. (fig. 8)

The surge arrester is now popular for wind turbine applications. There are several accessories for the surge arrester, for example: surge counters [3].

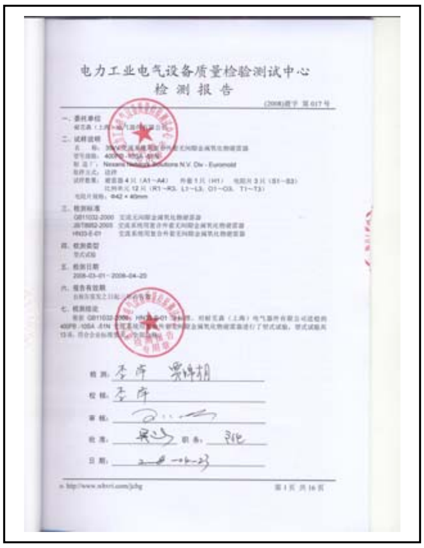
电力工业电气设备质量检验测试中心
检 测 报 告

Fig. 8: Test report Wuhan.

7. CONCLUSION

The Euromold shielded surge arrester protects expensive equipment because it is put directly on it. It is a compact solution since the surge arrester function is built in a 'male' rubber housing which is directly put into a rubber connector. Euromold extended the product range to 41 kV, which is the highest achievable voltage class for this application.

Reference list

[1] ABB HIGH VOLTAGE TECHNOLOGIES LTD, Application guidelines overvoltage protection: Dimensioning testing and application of a metal oxide surge arrester in medium voltage networks, Wettingen Switzerland, July 1999

[2] *IEC60099-4* Part 4 Metal-oxide surge arresters without gaps for a.c. systems, 2nd edition, 2004-05

[3] ABB AB HIGH VOLTAGE PRODUCTS, High Voltage Surge Arresters Buyer's Guide, Ludvika, Sweden, 6th edition, August 2008