FRENCH SERVICE EXPERIENCE WITH MV POLYMER HOUSED SURGE ARRESTERS

Frédéric MACIELA
EDF-DER Les Renardières
F-77818 Moret-sur-Loing (France)
Tel : +33 1 60 73 73 47 - Fax : +33 1 60 73 69 56
E-mail : frederic.maciela@edfgdf.fr

Patrick LE ROUX
EDF-DEGS / CETE
17, Place des Reflets
F-92080 PARIS LA DEFENSE

Christian GAZZOLA
FERRAZ
Rue Vaucanson
F-69720 Saint-Bonnet-de-Mure

Frédéric MALPIECE
SOULE Matériel Electrique
33 avenue du Général Leclerc
F-65203 Bagnères-de-Bigorre

Serge TARTIER
SEDIVER
F-03270 Saint-Yorre

ABSTRACT
This paper presents the main technical requirements for surge arresters installed on EDF distribution networks. In order to select high quality products, the importance of appropriate type tests during qualification is shown. In particular, besides the basic electrical properties of the metal oxide blocks, a special attention must be paid to both the ageing of the polymeric housing and the water tightness of the arrester.
Our field experience (about 800,000 polymeric surge arresters installed since 1992) gives clear indication of a very satisfactory behaviour, with an average failure rate of about 0.03 % a year. The reasons for failure are detailed and discussed.

EDF DISTRIBUTION ARRESTERS : POLYMER HOUSED SURGE ARRESTERS

At the beginning of the 90's, EDF decided to install polymeric surge arresters on its distribution networks. This choice followed two previous technical stages, namely silicon carbide gapped arresters (associated with a disconnector) and porcelain housed metal oxide arresters. These equipments were heavy and bulky, and their installation conditions were not optimized (long connection leads). Moreover, these designs are more sensitive to moisture ingress, and require a very careful assembly procedure at the manufacturing stage.
The main reasons for the changeover to the polymeric technology were significant improvements of the products themselves (performance associated to a simpler design, a safer behaviour in case of failure, an easiness to be braught into operation for live working) an optimized installation (better efficiency) and an optimization of costs.

ELECTRICAL DESIGN

Main guidelines

The good behaviour of surge arresters, whatever their technology is, mainly depends on the electrical design, which must fit the service conditions.

Continuous electrical stresses

The design for continuous operating voltage and for temporary overvoltage withstand was made taking into account that the arresters would be installed with neither air gap nor disconnector. So, the active core of the arrester (metal oxide blocks) and the polymeric housing are continuously energised. The reliability of all components of the arresters must then be irreproachable.

At the time when the developpement of polymeric arresters was conducted, EDF neutral grounding was made through a limitating resistor. However, EDF had a future project of neutral grounding through a compensating coil, which would allow running of the network even in the case of single phase faults, leading to increased voltages on the other phases. Hence the rated voltage was chosen at a rather high value (24 kV rated for a 20 kV nominal system voltage) so that the arresters can withstand a significant increase of the applied voltage for quite a long duration.

Ageing of the blocks

As the metal oxide blocks are continuously energised, ageing may occur and high quality blocks should be used. All blocks used in EDF arresters have passed a 1000 hours ageing test at 115 °C in a vessel filled with nitrogen (N_2). Due to the lack of oxygen, this medium gas actually stresses the blocks, and this is also a way to check that both the coating and the metallization are suitable.

Additional feature : the fault indicator

In case of failure, the arrester causes a permanent short circuit on the line as it is not fitted with a disconnector. This choice was made in order to avoid leaving failed arresters on the network. This operation policy can be acceptable only if the arresters are very reliable. Each arrester is equipped with a fault indicator to facilitate its location in case of failure. The sensitivity of the fault indicator is compatible with the very low short-circuit current levels (15 A) measurable in compensated systems.

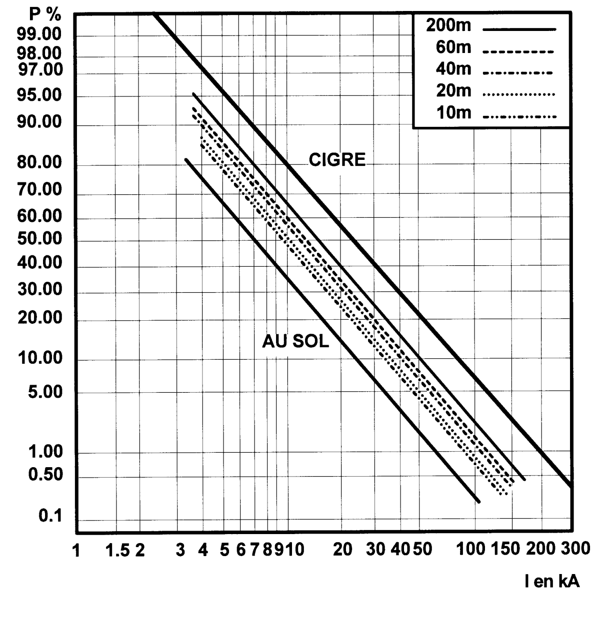
ENERGY ABSORPTION CAPABILITY : A BASIC STAGE FOR REACHING A HIGH QUALITY LEVEL

On distribution networks, the main energy stresses are due to lightning transient overvoltages. In order to design distribution arresters, it is then necessary to determine the current magnitude and the duration of lightning surges through surge arresters in the field, and to assess the frequency of these surges.

Parameters for lightning impulse energy design

Peak value of the lightning current impulse

The height of distribution lines is in the range of 5 to 6 meters above the ground. To determine the magnitude of lightning impulse overvoltages, the distribution curves shown below are commonly used. They take into account positive and negative flashes for high structures (such as towers or chimneys), and we consider that the magnitudes for the distribution networks should be taken between the curves “10 meters” and “ground level”.



Waveshape of the lightning impulse

The half value time (called tq) of the lightning current impulse is considered to be distributed as follows :

- 95 % of strokes with tq > 30 µs
- 50 % - - with tq > 75 µs
- 5 % - - with tq > 200 µs .

Non-linearity of the metal oxide stack

To be able to evaluate the energy dissipated in a surge arrester, it is necessary to take into account the non-linear ohmic resistance of the metal oxide blocks.

The results of energy calculations are given for the standard “4/10µs wave” of the IEC operating duty test :

- 29 kJ for a peak current value of 40 kA
- 52 kJ for a peak current value of 65 kA .

Calculations were also made for other waveshapes :

- 4/75µs, î = 10 kA .... E = 56 kJ
- 4/200µs, î = 5 kA .... E = 70 kJ
- 4/200µs, î = 10 kA .... E = 152 kJ .

Those results show that an important amount of energy may be dissipated in a surge arrester, even if the peak value of the current is low because it depends on the waveshape. This paper will assume that the reference energies are 29 kJ and 52 kJ with respect to 4/10µs impulses with 40 kA and 65 kA peak current values.

Distribution of lightning current impulses

Another important parameter for the energetic design is the actual value of the current which flows through the arrester. This value mainly depends on :

- the grouding impedance
- the insulation coordination of the line (probability of flashover between phases)
- the distance between the surge arrester and the point of impact .

We can consider three different hypothesis : the current through the arrester is either I_f, or I_f / 2 or I_f / 3, where I_f is the peak value of the direct lightning flash.

Keraunic level : probabilistic approach for energetic design

In France where the average keraunic level is about 22.5, and for our distribution networks, the frequency of direct lightning flashes is about 0.018 per year and per substation.

If we consider the probabilities for direct lightning peak current and waveshape, the following table can be drawn:

Current	If / 3 Simple stroke	If / 3 Multiple strokes	If / 2 Simple stroke	If / 2 Multiple strokes	If Simple stroke
Design energy (kJ)	29 / 52	29 / 52	29 / 52	29 / 52	29 / 52
Prob. of Failure ($^0/_{00}$)	***1.9 / 1.0***	***2.1 / 1.3***	***2.5 / 1.5***	***2.9 / 2.0***	***3.9 / 3.0***

The last line of this table gives the probabilities of energy overstress on distribution arresters with regard *to two energetic design levels (29 kJ and 52 kJ) for a keraunic level equal to 22.5*

These calculations indicate that, in France, a surge arrester designed for an energy absorption capability of 52 kJ (corresponding to a 4/10µs 65 kA current impulse) has a failure risk lower than 0.2 %, and more probably close to 0.1 %.

This calculation method was used at EDF to reach a compromise between risk of failure and arrester energy performance. The choice was made to design distribution metal oxide surge arresters for 4/10µs 65 kA current impulse, considering that a failure rate of about 0.1 % is acceptable to quality of service.

OTHER IMPORTANT PARAMETERS FOR THE RELIABILITY OF POLYMERIC ARRESTERS

In addition to the required electrical performance, polymeric surge arresters must be watertight and possible ageing of their housing must be really kept under control so as to guarantee their satisfactory behaviour during the expected lifetime. To check so, a technical evaluation of the products with serious test procedures and relevant sanctions allow very good results to be obtained.

Water tightness of the arrester

Moisture ingress is the worst event which may occur. Indeed, it cannot be easily detected on the line, and inescapably leads to electrical failure of the arrester.
The sealing of arresters must then provide a perfect tightness under all conditions (mechanical loading, thermal cycling, ...). Corrosion of metallic parts must not damage the sealing system either.
The future IEC draft for type testing of polymeric surge arresters will specify a complete test to check their water tightness and their thermo-mechanical properties. Distribution arresters qualified at EDF were tested in a similar way, i.e. using test sequences including mechanical pre-conditionning, immersion in boiling water during 42 hours and final electrical verifications.
Moreover, the manufacturer must be able to keep manufacturing processes under close control to be sure that the tightness of his arresters is guaranteed.

Ageing of the polymeric housing

All polymeric materials are exposed to ageing phenomena, which may affect tightness and insulation properties of housings. For many years EDF has carried out studies and comparisons between natural ageing and accelerated ageing tests. A lot of polymeric materials were tested during many years in the EDF natural ageing laboratory of Martigues, located on the Mediterranean coast near a petro-chemical plant. There, pollution can reach very high levels. Accelerated weather ageing cycles were performed on the same materials in the laboratories of Les Renardières.
The main conclusion of these investigations is that an accelerated ageing test shall apply combined stresses to the housing under test, namely UV radiations, salt fog, rain, temperature and voltage. The test procedure used at EDF is the 5000 hours weather ageing test described in IEC 1109 standard.

Time (hours)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
VOLTAGE	X	X	X	X	X	X	X	X	X	X	X	X
RAIN	X											
HEATING		X	X				X	X				X
HUMIDITY			X					X				
SALT FOG				X	X				X	X		
UV	X	X				X	X				X	X

IEC 1109 weather ageing daily cycle (5000 h test)

This picture shows a transformer protected by polymeric surge arresters (horizontal) and fuses (vertical)

SERVICE EXPERIENCE

Organization of the service experience

EDF has developped an organization to collect service experience data for polymeric surge arresters. The main features of this organization, which has been in place since 1992, are :

- each failure of a surge arrester is directly recorded by operators in a failure file, providing information about the location, date of installation, the atmospheric conditions during the failure, all other events of interest
- all failure files are sorted
- the failed arresters corresponding to an electrical failure, or to a new failure type, are sent to the EDF research division for damage survey (including electrical testing)
- the failed arresters corresponding to well known types of failure are directly shipped to the manufacturers for damage survey
- every year, EDF and the manufacturers meet to analyse the situation and draw up statistical data.

Main results

About 800,000 polymeric surge arresters were installed on EDF distribution networks since 1992. The failure rate of these arresters is as low as 0.03 % a year.
The electrical failures (energy overstress on the blocks) represent less than 0.005 % a year.
All the other failures are related to mechanical problems (for example bolt jam at the installation stage), flashover due to boughs of tree or spontaneous triggering of fault indicators.
Neither moisture ingress nor ageing of the polymeric housing was reported, and no flashover occurred due to pollution events. EDF is keeping a close eye on these three points, because of their great importance for the reliability of the surge arresters.

CONCLUSION

EDF field experience with polymeric surge arresters is very positive. No problem having serious consequences on the network operation has been recorded up to now.

The energy absorption capability of the blocks (5 kA nominal discharge current, 65 kA high current impulse withstand) leads to a very satisfactory electrical behaviour.

These good results seem to be explained by a selective qualification of the arresters, rigorous manufacturing processes and an organized field experience where each failure is recorded and discussed with the manufacturers.