A COMPARISON OF THE PERFORMANCE OF SURGE PROTECTION DEVICES UNDER LONG DURATION DC-CURRENTS

Jan Meppelink; Peter Kurzidim
Meppelink@T-Online.de
Fachhochschule Südwestfalen, University of Applied Sciences, Germany

JürgenTrinkwald
Trinkwald.tsb@obo.de
OBO Bettermann, Germany

Abstract: Long duration currents can stress surge arresters in low power mains. Especially in a TT-net the N-PE spark gaps are the most stressed gaps. The standards define the test parameters. Tests on class I arresters with spark gap and class I N-PE spark gaps of different technology are described. The main aim is the show the advantages of graphite as electrode material. The generation of long duration currents up to 400A for a duration of 0,5 s is described.

Keywords: Long duration current, Charge, Lightning arrester, TT-net, DC generation

1. INTRODUCTION

Long duration currents in low power mains may occur in case of direct or indirect lightning strokes. Do they stress surge arresters and N-PE spark gaps? The overvoltage protection technology was mainly focussing on the impulse currents and accompanied by the standardisation as well. On the other hand the standards /1/ refer to long duration currents as a root for melting processes e.g. on metal sheets. In a study the impact of long duration currents was analysed using a computer model and the performance some commercial available surge arresters was tested in the laboratory.

2. THE IMPACT OF LONG DURATION CURRENTS ON LOW VOLTAGE POWER MAINS.

From the physics of lightning /2,3/ it is well known that long duration currents occur. The magnitude of the current of some 100 A is low compared to impulse currents but the duration is in the range of some 100 ms. Table 1 shows the parameter of a long duration current according to /1/. The charge of a long duration is large and therefore the energy dissipation on arc footing points is of major impact. Therefore the long duration current may cause melting of metallic electrodes of spark gap arresters.

First of all the current distribution in case of a stroke into the overhead line or into the external lightning protection was studied. Fig. 1 shows a simplified circuit with a building including a TT-net installation. Using a computer programme /4/ the current distribution was determined. In case a) the overhead line will be hit by a lightning stroke. In case b) the building itself with a lightning protection system will be hit. The results are shown in table 2.

Case a) Direct stroke into overhead line

The phase arresters as well the N-PE spark gaps are not really stressed because the long duration current will flow through the transformer winding to ground. Only in case of very long overhead lines the phase arresters may be triggered and will take a certain part of the current which depends on the actual configuration. In case of a previous impulse current the phase arresters may be still in conductive state and they will lead also part of the long duration current until the gap extinguishes after current zero.

Case b) Direct stroke in the external lightning protection system of a building

The worst case is a TT-net. In case of high earthing resistance of the local grounding resistance the N-PE spark gaps in a TT-net installation will be stressed with the full long duration current. The phase arresters are not stressed. From the results one can conclude that the N-PE spark gaps have to be tested with the full range of long duration currents. In addition the phase arresters with spark gaps should also be tested to cover the full range of application in the world.

Table 1 Parameters of long duration current /1/

Parameter	Protection Class			Tolerance
	I	II	III und IV	
Charge Q C	200	150	100	± 20 %
Duration T s	0,5	0,5	0,5	± 20 %

3 GENERATION OF LONG DURATION CURRENTS IN THE LABORATORY

Fig.2 shows the circuit for the generation of long duration currents up to 500 A. The current source is a 870 Volt battery which allows also the generation of long duration currents in discharges with higher arc voltage e.g. during melting experiments on metal sheets. The current duration is controlled using an IGBT. The gap is triggered using a parallel 10/700µs lightning impulse voltage generator. If the spark gap is triggered with the trigger voltage 10/700µs the sensor as shown in fig.2 switches the IGBT and starts the long duration current flow through the gap. The actual DC current was measured using a commercial DC current transformer with a bandwidth of some kHz. DC tests are very dangerous as far as the vapour of molten metal or plastic as well as the welding effect (e.g. Fig.4) is concerned. Therefore

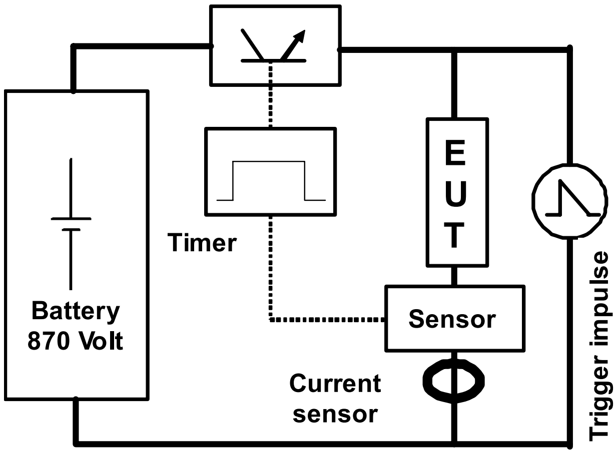

Fig. 2 Principle of long duration current generation. EUT: Tested spark gap

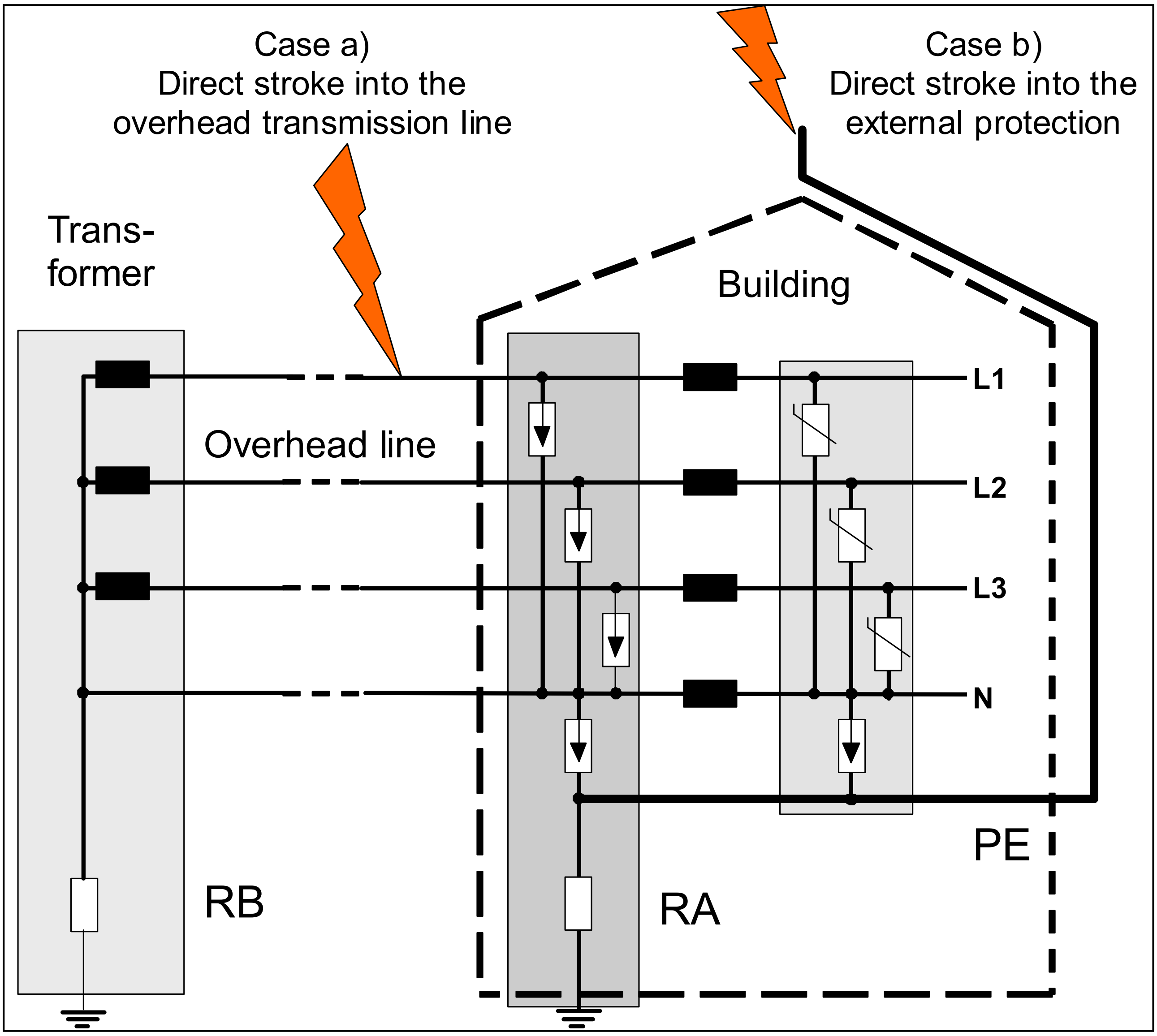

Fig. 1 Simplified circuit for the calculation of the current distribution in case of long duration current injection in a line or in the external lightning protection.

the experiment is protected using a DC circuit breaker which interrupts the current in case of a failure. The tested spark gap is placed inside of a transparent box as shown in fig.4,6. With the described generator tests could be safely performed.
Fig.3 shows an example of a 220A /110As long duration current through a spark gap.

4 EXPERIMENTAL RESULTS

Various commercial available spark gaps were tested. They can be divided into such with graphite electrodes and such with metallic electrodes. Some of the gaps are inside sealed housings and others are inside housings with openings for plasma release of the arc in the gap.
The results will be shown in detail on one sealed N-PE spark gap with graphite electrodes and one N-PE spark gap with an open Phase arrester with metal electrodes.

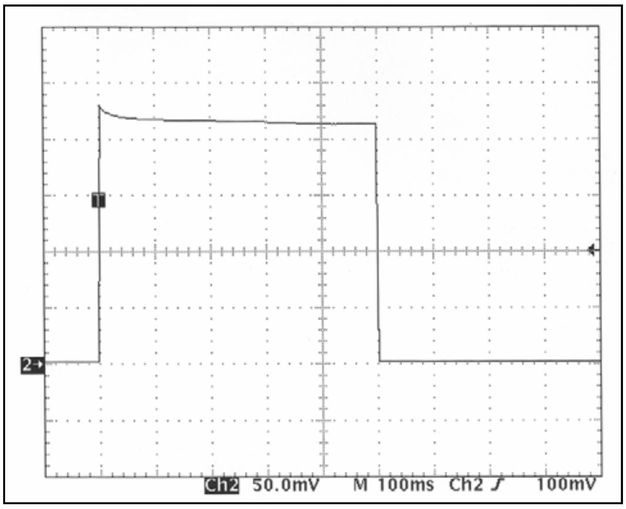

Fig.3 Example of a long duration current impulse. Scale: 50A/DIV, 100ms/DIV

Table 2 Results of the computer simulation

	Case a) Direct stroke into the overhead transmission line		**Case b) Direct stroke into the external protection**	
Impact of long duration current on:	Long duration current only	Combination of impulse current and long duration current	Long duration current only	Combination of impulse current and long duration current
Lightning current arrester Class I, mainly a spark gap arrester	No spark-over of the arrester. The DC current can flow into the transformer.	The spark gap will extinguish after current zero. The remaining DC current will flow into the transformer.	No impact	The spark gap will extinguish after current zero. The remaining DC current will flow into the neutral conductor.
Surge arrester, Class II, mainly metal oxide arrester	A negligible part of the DC current will flow into the arrester	An impulse current will flow until the class I arrester has taken over the current.	No impact	An impulse current will flow until the class I arrester has taken over the current.
N-PE-Spark gap in a TT-net together with a class I lightning current arrester.	No impact	No impact	**Depending on the earthing resistance in a TT-net the full long duration current can flow into the N-PE spark gap.**	**Depending on the earthing resistance in a TT-net part of the impulse current and the full long duration current can flow into the N-PE spark gap.**
N-PE-Spark gap in a TT-net together with a class II surge arrester.	No impact	No impact	**Depending on the earthing resistance in a TT-net the full long duration current can flow into the N-PE spark gap.**	**Depending on the earthing resistance in a TT-net part of the impulse current and the full long duration current can flow into the N-PE spark gap.**

Fig. 4 Class I arrester with open metal electrodes and under test with a current of 400A/0,5s.

4.1 Class I arrester with one open gap with metal electrodes.

Fig 4 shows the exhaust of hot plasma out of the hosing under a long duration current according to fig.5. The arc voltage is in the order of 20 volt and caused by the anode and cathode voltage drop as known for a metallic gap with one electrode. The arc voltage is in the order of some 100 volt due to the extension of the arc in the arc interruption chamber. The arc voltage shows some fluctuation due to the extinguishing arc and reignitions of the gap during a 200 As test.

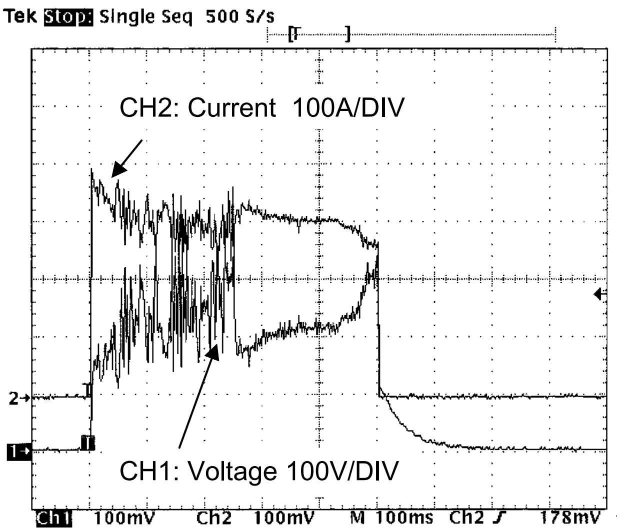

Fig.5 Voltage und current during a test on the class I arrester as shown in fig.4.

Fig. 6 Class I N-PE spark gap with grafite electrodes in a sealed housing under test with a current of 400 A/0,5s.

4.2 Class I N-PE gap with two spark gaps with grafite electrodes and sealed housing.

Fig. 6 shows the arrangement. Fig 7 shows the corresponding shape of the current and the voltage measured during a 200 As test. The arcing voltage of the gap is in the order of 40 Volt and is caused by the anode and cathode voltage drop of the two spark gaps. Compared to fig. 5 there is a smooth curve for the arc voltage because the arc length in the grafite gap is in the mm range.

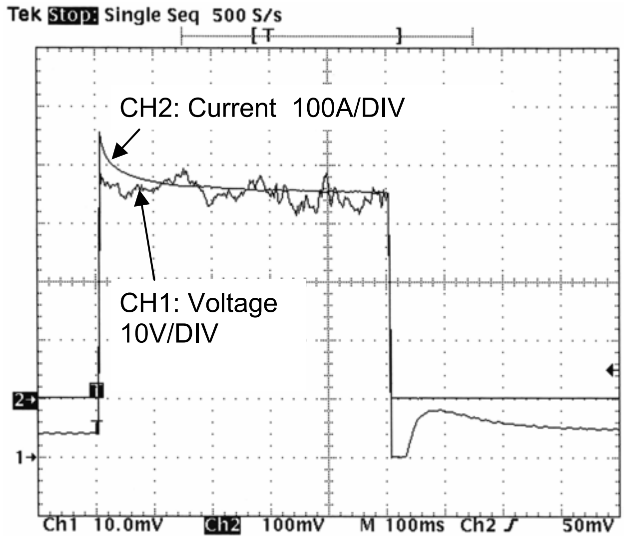

Fig.7 Voltage und current during a test on the class I arrester as shown in fig.6.

5 COMPARISON OF TECHNOLOGIES OF CLASS I ARRESTERS UNDER LONG DURATION CURRENTS.

The aim of this investigation was the comparison of different technologies of class I spark gap arresters as well as Class I N-PE spark gaps under long duration currents. The main focus was the comparison of arresters with spark gaps made from metal electrodes and those with graphite electrodes.

5.1 Comparison of Class I N-PE spark gaps

The N-PE spark gaps can be stressed with the full level of a long duration current, as shown in table.2. First of all the spark-over voltage 1,2/50µs was measured using 5 impulses for each sample. After the application of the long duration current the spark-over voltage was measured in the same way. The results are shown as a normalized spark-over voltage in fig 8 for a long duration current of 100 As and in fig. 9 for a long duration current of 200 As.
In general the metal electrode spark gaps show a decrease of spark-over voltage due to the melting effects on their metal surface which corresponds to a lower spark-over voltage. Graphite electrodes behave different from metal electrodes. Due to the absence of metal there is no metallic vapour and in case of graphite there is no melting of a surface of the electrodes.
An other set of new samples was tested with a long duration current of 200 As. The results in fig. 9 show even a total damage of one of the sample with metal spark gap.

5.2 Comparison of Class I spark gap arresters

As shown in table 2 the phase arresters are less stressed compared to the N-PE spark gaps. However for comparison of technologies a set of samples was tested with 3 different prospective charges. In some cases the arc voltage of a gap was such high that the prospective long duration current was interrupted because the battery with a voltage of 870 volt. Therefore the results are shown in the fig. 10,11 versus the effective applied charge. First of all the spark-over voltage 1,2/50µs was measured using 5 impulses for each sample. After the application of the long duration current the spark-over voltage was measured in the same way.
Fig.10 shows the results for positive polarity of the spark-over voltage 1,2/50µs. Graphite spark gaps as indicated with A in fig.10 could be tested up to 60 As due to their smooth and constant arc voltage with good results. The spark-over voltage did not change. But also one of the metal spark gap arrester C in fig.10 could be

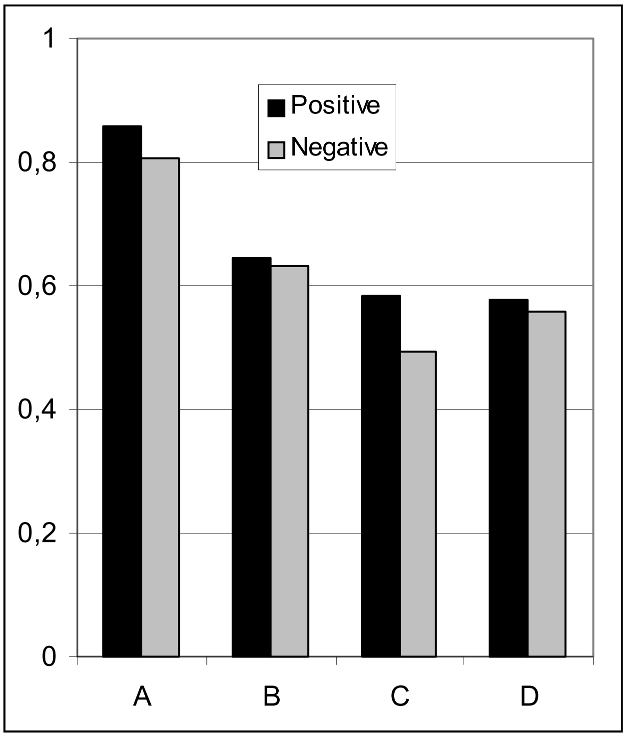

Fig. 8 Normalized spark-over voltage1,2/50µs of class I N-PE spark gaps after the application of one long duration current with a charge of **100 As**.
A: Double grafite spark gap in closed housing
B: Single metal spark gap in closed housing
C: Other single metal spark gap in closed housing
D: Other single metal spark gap in open housing

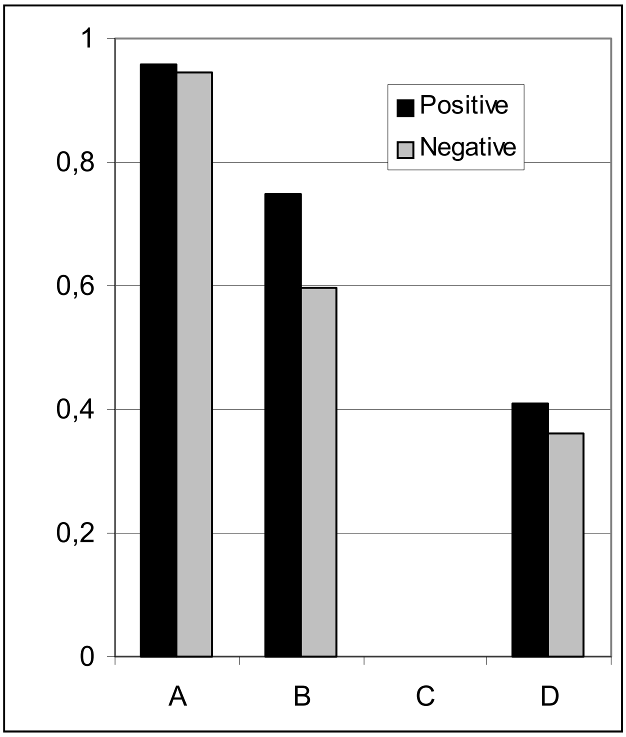

Fig. 9 Normalized spark-over voltage 1,2/50µs of class I N-PE spark gaps after the application of one long duration current with a charge of **200 As.**
A: Double grafite spark gap in closed housing
B: Single metal spark gap in closed housing
C: No test possible because of failure in 100 As test.
D: Other single metal spark gap in open housing

tested up to 70 As. Most of the other gaps show a good performance, others show a strong increase of the spark-over voltage 1,2/50µs. Other gaps could be tested to 20As only due to the high arc voltage. In case of a real long duration current as a " lightning current source" the energy dissipation would be quite high and other results have to be expected. Some samples, E,F, were destroyed during the test.
The results at negative polarity are shown in fig. 11 but similar to the results obtained at positive polarity.

6 CONCLUSION

Long duration currents up to 200 As charge can be generated in laboratory. The length of DC-arcs is limited by the driving voltage of the DC source.
Class I spark gap arrester as phase arrester have shown a good performance. They are stressed with long duration currents only in special cases of very long overhead lines.
The class I N-PE spark gaps are the most stressed gaps in case of a TT-net. The results of the performed tests show that N-PE gaps with metal electrodes have a decrease of the spark-over voltage 1,2/50µs. One of these samples failed under 200 As test condition.
The great advantage of graphite as electrode material was confirmed in these tests. N-PE spark gaps with graphite electrodes could withstand up to 200 As applied charge without a loss of performance.

7 REFERENCES

/1/ IEC 61312 Protection against electromagnetic impulse– Part 1:General principles
/2/ K.Berger: Novel Observations on Lightning Discharges: Results of Research on Mount San Salvatore. Journ. Franklin Inst.,283 (1967), S. 478-525.
/3/ Cianos,N, Pierce, E.T. :A Ground-lightning environment for engineering usage. Technical report Stanford University
/4/ Microcap 7.0: Electronic Circuit Analysis Program. www.spectrum-soft.com.

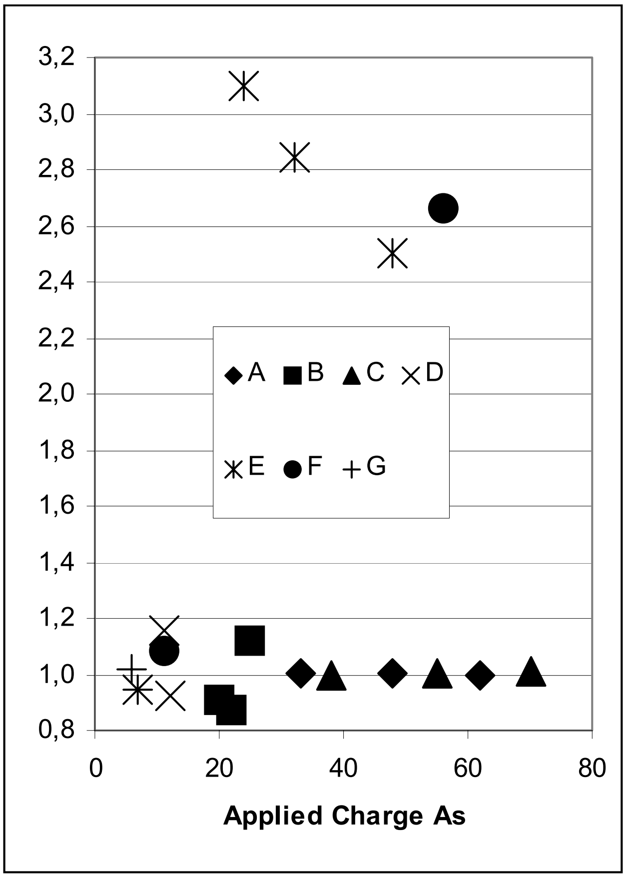

Fig.10 Normalized spark-over voltage of various Class I arresters versus applied charge at positive polarity.
A: Multiple grafite spark gap in closed housing
B: Single metal spark gap in closed housing
C,D,E,F,G: Single metal spark gap with open housing

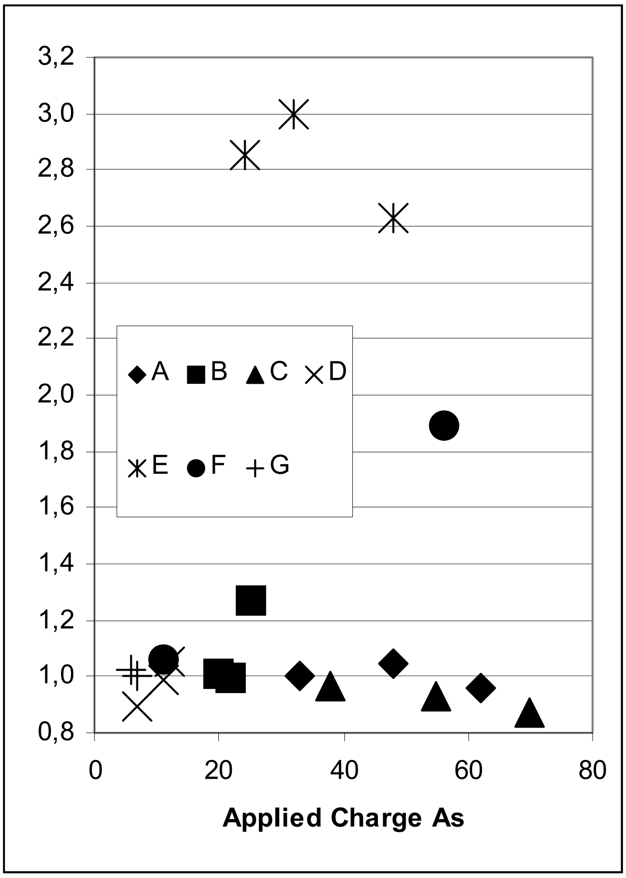

Fig.11 Normalized spark-over voltage of various Class I arresters versus applied charge at negative polarity.
A: Multiple grafite spark gap in closed housing
B: Single metal spark gap in closed housing
C,D,E,F,G: Single metal spark gap with open housing