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INFLUENCE OF THE AC SURGE PROTECTORS TECHNOLOGY ON THE QUALITY OF AC DISTRIBUTION NETWORK

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Since years the Surge Protective Devices (SPD) are widely used to protect the sensitive equipment connected to the AC distribution network against lightning or switching surge voltages. The international standards for SPDs are now widely spread and make the new generation of AC surge protectors more efficient and more secure.

But an important issue is not really described on the standards and even on the related guides for surge protection application: what is the real influence of the AC surge protector on the AC network, especially during their operation? As we know, the Power Quality (PQ) is a key point for the process continuity, the safety and even for the life expectancy of the sensitive devices connected to the AC distribution network: during their operation on surges, the surge protectors could generate some phenomena which could create disturbances or troubles on the AC network. Because the AC surge protectors are from different technologies and because the AC networks could have several configurations, many cases are possible, even the worse…

Market analysis shows sometimes a low confidence of the end user in the surge protection, not because he thinks it is not efficient, but because he supposes the use of SPD could bring extra disturbances on his installation. For this reason, an in depth information about the real interaction would be useful.

1 INTRODUCTION

The target of this study is to describe and to test the real effect of the AC surge protectors (SPD : Surge Protective Devices) on AC distribution network, in relation with the different SPD technologies used today on the market, with the different types of AC network and the different type of incoming surges. The consequences of the behaviour on the operation of the devices connected to the network will be analysed.

2 DESCRIPTION OF THE STUDY

The process of the study could be described as the following:

- Choose the SPDs
- Define the AC network
- Define the surge generator
- Test the SPDs following the standards
- Record the results on the AC network
- Compare with a computer model
- Conclusion

A. Surge Protective Devices

It have been chosen to focus the study on Type 1 SPDs, because in this specific range of AC surge protectors, two different technologies are commonly used : "Air Gap-based" SPD and "MOV-based" SPD. The behavior of each technology is different from the others : Air-Gap SPD operates as crowbar device, MOV SPD operates as Limiting device.

Note : The others types of AC SPDs (Type 2 and Type 3) are widely based on MOV components, which make a comparison study much less attractive.

Four different Type 1 SPDs have been tested: 3 Air-gap-based SPDs (all with triggering feature) and 1 MOV-based SPD (Multiple high energy MOV in series with high energy GDT (Gas Discharge Tube)). The SPDs have been chosen with similar electrical characteristics:

Table 1 – List of the tested surge protective devices

Samples	*Technology*	*Iimp/pole*	*Configuration*
SPD1	Trigger Air-Gap	25 kA	3Ph
SPD2	Trigger Air-Gap	25 kA	3Ph
SPD3	Trigger Air-Gap	25 kA	3Ph+Neutral
SDP4	MOV+GDT	25 kA	3Ph

B. AC network

The tests have been performed on 3-Phase 230/400 AC networks, in order to analyze the interactions on the different phases during the operation of the SPD.

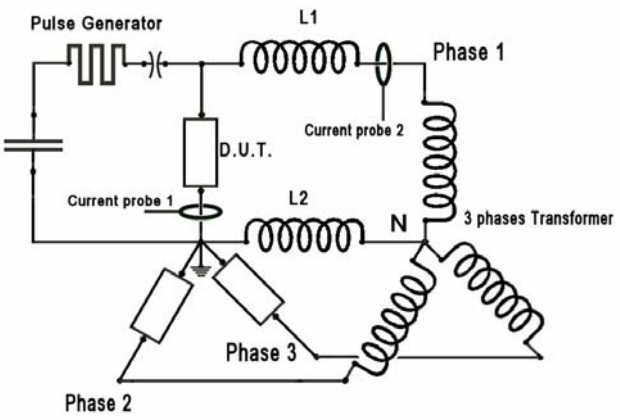

Fig. 1 – Description of the test circuit

The 3-phase AC network is made with 3 identical transformers with high insulation rating between primary and secondary windings (10 000 Vac). The secondary windings are connected in "star-diagram" with the central point as the Neutral point, in order to obtain 230 Vac between L/N and 400 Vac between L/L. Each transformer has a prospective short-circuit current capability of 1500 A.

The inductor L1 is used to block the surge current impulse coming from the surge generator, during the test injection.

The inductor L2 is used to simulate the length of conductor between the transformer and the surge protector: its rating will vary to test different configurations.

C. Surge Generator

The 'G100K' surge generator used is owned by GERAC test laboratory (Limoges, France): it delivers double-exponential waveforms in accordance with the requirements of IEC 62305-1 standard.

The system generates either 8/20µs or 10/350µs waveforms as required on any resistive load up to 100 mΩ.

The surge currents are adjustable from 5 to 100 kA.

Table 2 – Surge Generator Specifications

Wave shape	8x20µs	10x350µs
Amplitude	5 kA to 100 kA continuously adjustable	
Shape	double exponential	
Polarity	positive	
Rise time	8µs ± 20%	10µs ± 20 %
Width (FWMH)	20µs ± 20 %	350µs ± 20 %
Maximum output current	100 kA	100kA
Current stability	< 20%	
Overshoot - undershoot	< 10%	
Lifetime shots	100 kA: 50,000 shots 50 kA: 100,000 shots	100 kA: 50,000 shots 50 kA: 100,000 shots
Minimum time between two shots	1 mn (at 20kA - 8-20µs)	
Synchronisation with mains	accuracy ± 2°	

Fig. 2 – Surge Generator

D. Surge tests following standard

Each SPD has been first tested following the operating duty test of the IEC 61643-1 standard [1], in order to check their behaviour and especially the apparition or not of a follow current.

The test results are the following :

Table 3 – Follow current behaviour

Tests performed following IEC 61643-1 § 7.6. (Operating duty test) Preconditioning 15 impulses 25 kA 8/20µs Application of 5 x 10/350µs impulses with increasing peak values (0.1xIpeak , 0.25xIpeak, 0.5xIpeak, 0.75xIpeak and Ipeak)	
Test parameters (for all the SPDs)	
Nominal Discharge Current (In)	25 kA @ 8/20µs
Current peak value (Ipeak)	25 kA @10/350 µs
Max. Continuous Operating Voltage (Uc)	255 Vac
Prospective short circuit current (Ip)	1500 A

SPDs under test	**Follow current behaviour**	
	On the first impulse	During and After Test
SPD1	No follow current	On the 4th impulse duty test (18,75 kA) ➔ follow current
SPD2	No follow current	On the 4th impulse duty test (18,75 kA) ➔ follow current
SPD3	Follow current	On the 4th impulse duty test (18,75 kA) ➔ SPD Failure
SPD4	No follow current	No follow current up to the end of the test sequence

We can notice that some SPDs ((1) , (2)), based on air-gap technology, show a modification of their behaviour : no follow current at the beginning of the test, then follow current later in the test. We have stopped the operating duty test sequence as soon as a follow current is observed.
We can consider the change of the follow current behaviour observed on SPD1 and SPD2 as a kind of “ageing” of these air-gap technologies.
We have analysed the consequence of a follow current on the Power Quality of the network. The following tests conditions have been defined as 25 kA 8/20µs (standard preconditioning conditions) at 30° relative to AC phase network .

E. Influence of the voltage-current phase shift – Single Phase testing

The following record shows that the air-gap extinguishes at zero current crossing of the AC line. This is a very important aspect especially when a voltage-current phase shift may be induced by the power supply network. A sharp voltage transition is generated when the air-gap extinguishes. This point should be kept in memory because we have not given the current curve in some of the following diagrams for better diagrams readings

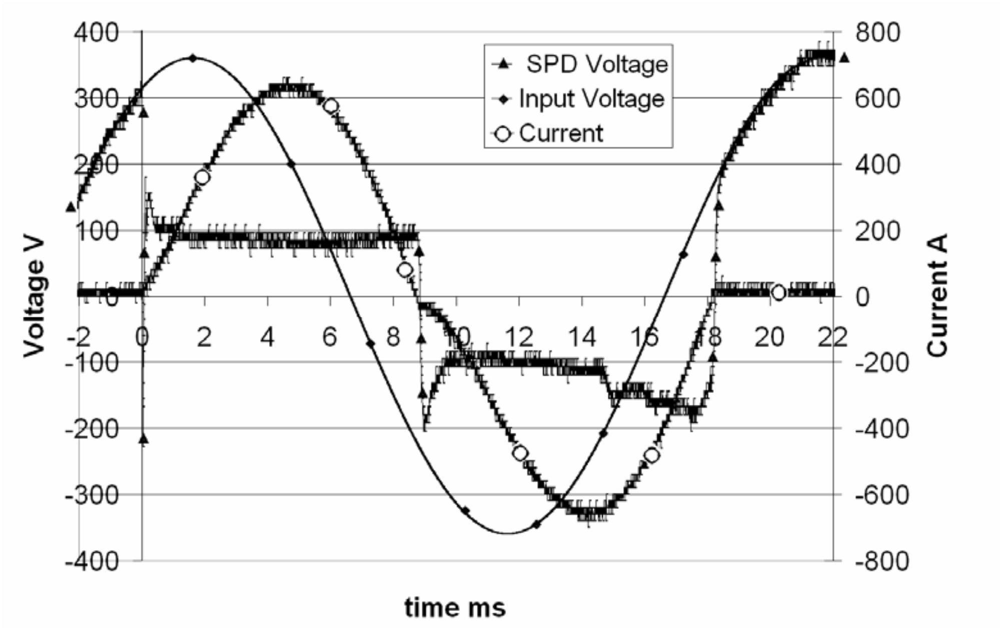

Fig 3 - SPD3 extinction operation with 900 µH inductor

A series of tests have been performed to analyse the influence of the voltage-current phase shift on the operation of the SPDs developing follow currents. This phase shift has been obtained by increasing the rating of the N-PE inductor (L2) from 80 µH, to 247 µH then 900 µH.
The result below shows that higher is the phase shift, longer will be the follow current duration: e.g for 900µH inductance, the SPD needs up to 18 ms to stop the follow current and recover its insulation. The phase shift will induced an open circuit voltage at the zero current crossing that may become high enough for the air-gap to self trigger. In this example the voltage limit for self triggering is 200V

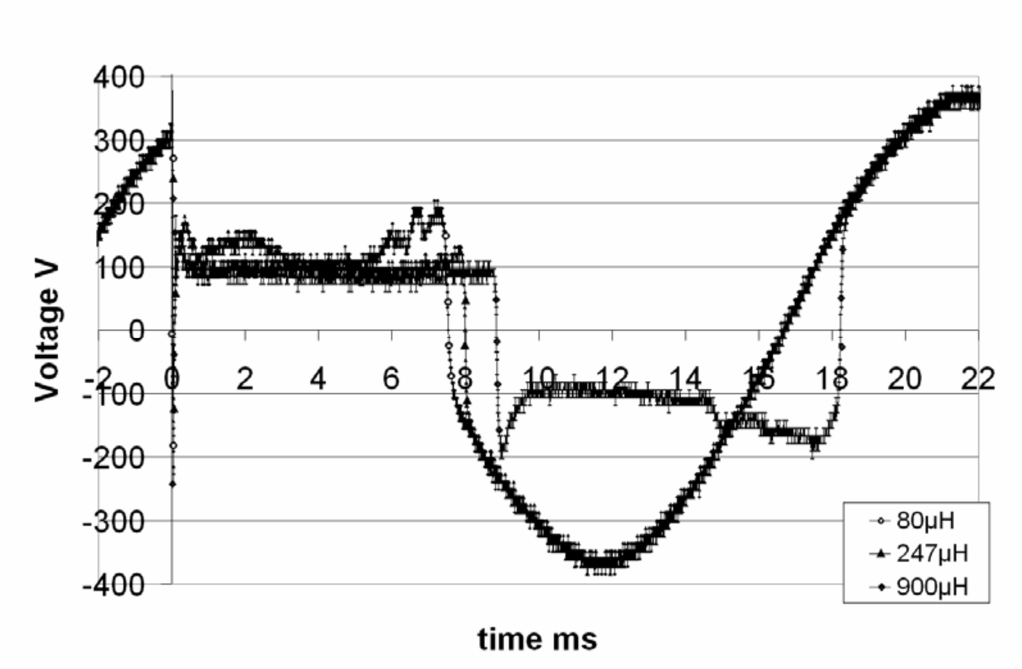

Fig 4 – SPD extinction vs voltage-current phase shift

F. AC voltage recordings – 3- Phase testing

Each SPD has been first tested following the pre-conditioning test of the IEC 61643-1 standard [1], with 8/20µs surge injection (20 kA rating), in order to obtain clean and relevant recordings and L2 inductance set at 827µH. We can see two typical behaviors : with or without follow currents.

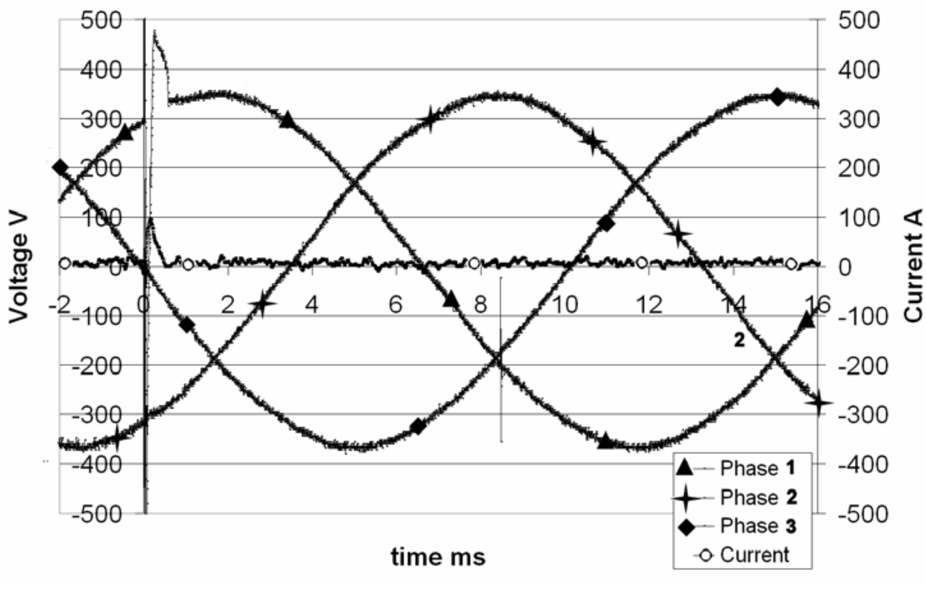

Fig 5 - SPD4 (MOV technology) : no follow current

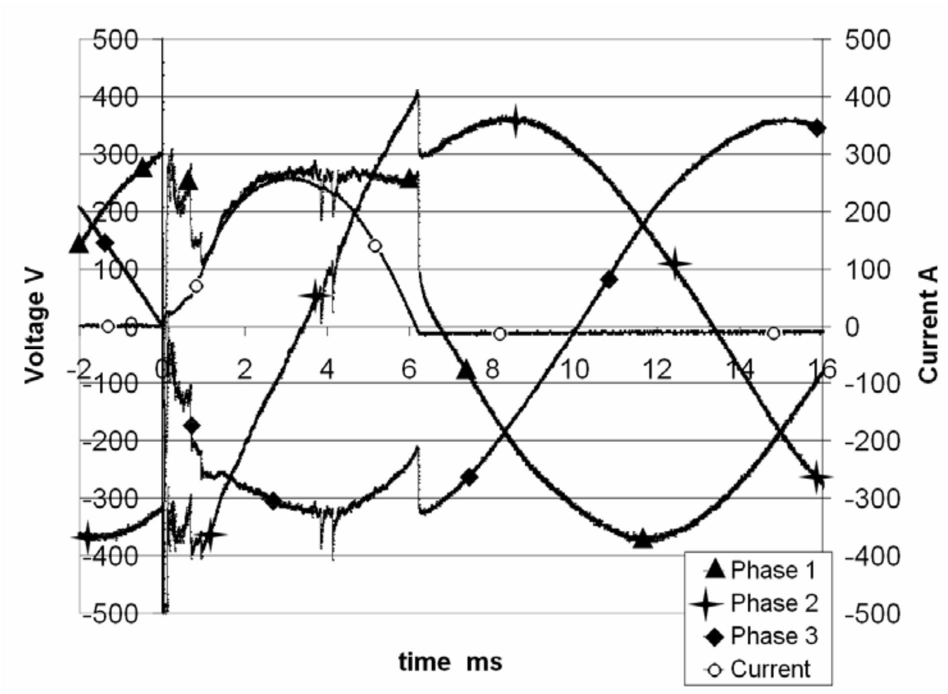

Fig 6 - SPD1 (Air Gap technology) : follow current

The comparison of these 2 recordings shows the obvious influence of the follow current behaviour on the quality of the AC voltage :

- Fig 6 : the SPD1 creates voltages disturbances (sags) on the 3 phases as well as a 260 amperes current to ground during 6 ms.
- Fig 5 : In the other hand, the SPD4 based on MOV has also no bad effects on the quality of the AC network.

G. Computer model

In order to check the relevance of these measurements, a computer model has been designed. The result below is in very good agreement with the observed data:

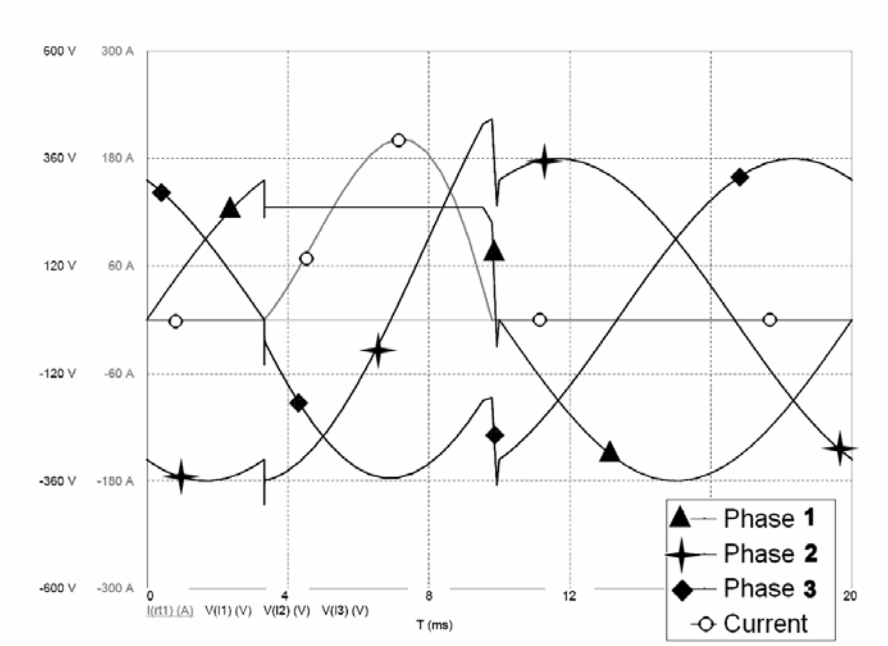

Fig 7 - SPD1 (Air Gap technology) : Computer model of the Fig 6

H. Multiple surge injection

Other tests have been performed with multiple surge injection on each phase simultaneously. The coupling of the voltage surges on AC was done through 10µF capacitors (diagram below). A such configuration can not allow large values of surge current but has been enough to trigger the air-gaps with a 25 kA 8*20 pulse injected in the 0.1Ω resistor..

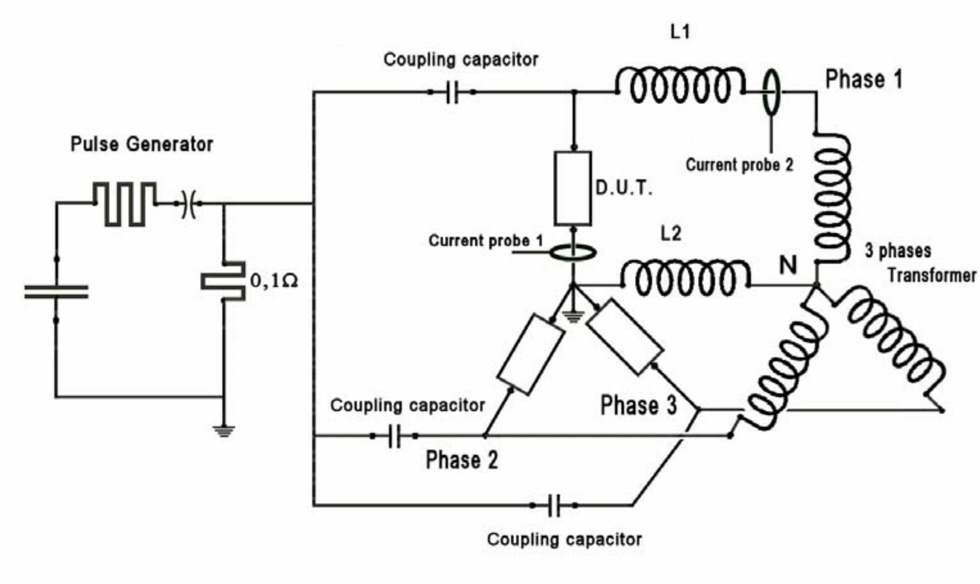

Fig 8 – Multiple surge injection diagram

The recording below shows that a multiple surge injection, even with only a very low energy impulse (2.5 kV peak voltage), creates even more disturbances in the AC voltage.

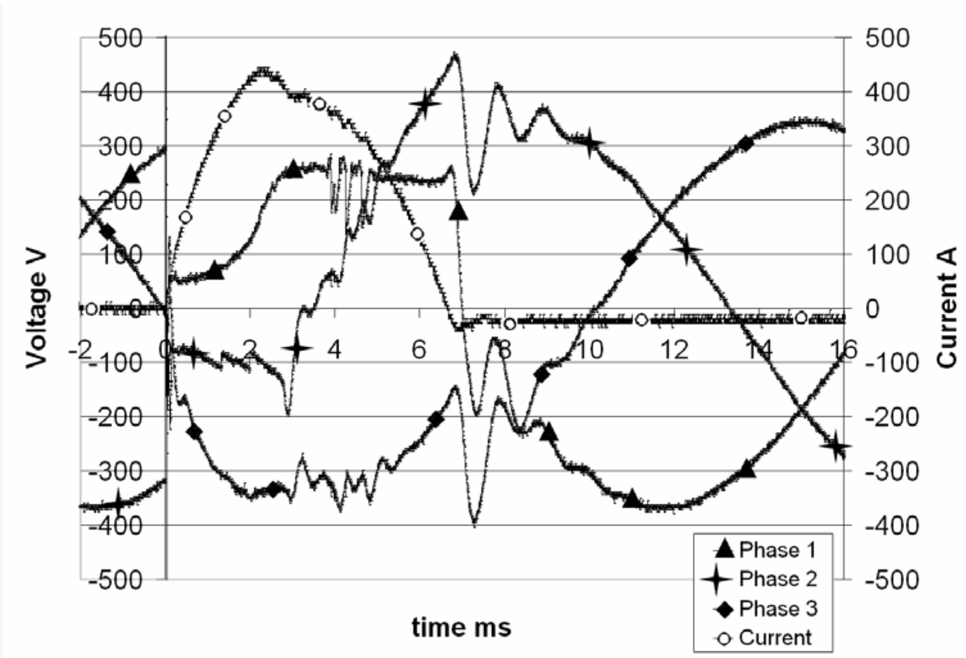

Fig 9 – Voltage disturbances on multiple surge injection

It should be noticed that the damped oscillatory voltage curves after the air-gap extinguish at 7 ms are artefacts produced by the coupling capacitors.

I. Conclusions

Several conclusions could be claimed following these tests:

- Some SPDs based on air-gap technology have a changing behaviour regarding follow current : a “ageing” process seems to occur in relation with the number of conducted surges.
- The phase shift between voltage and current has an important influence on the duration of the follow current and the ability of the air-gap to extinguish.
- The follow current appearance creates important disturbances in the AC voltage distribution
- Multiple surge injection increases the disturbances.
- We have developed a computer model which is in very good accordance with the observed data. This model could help to simulate actual configurations that could be very difficult or very expensive to check in other ways.

Further tests will be performed in order to provide more in-depth information. about this sensitive problem of influence of the SPD operation on the quality of the AC voltage.

J. Acknowledgement

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We would want also to thank Mr Mirko Harbott for his efficient design of the computer model used in this paper.

K. References

[1] IEC 61643-1 : Surge protective devices connected to low voltage power distribution systems - Part 1: Performance, requirements and testing methods", 2002.