

Coordination Tests between SPDs and between SPD and Equipment

Alain Rousseau, Gilles Rougier
SEFTIM

Vincennes, France
alain.rousseau@seftim.fr

Zhao Yang, Zhou Qibin
Shanghai Lightning Protection Center

Shanghai, China
zhaoyang@lightning.sh.cn

Abstract— There are many problems on the field regarding SPD selection and coordination.

As a matter of fact, there may be SPD from many manufacturers on the same line. One SPD is installed by the contractor in charge of electrical installation and then various panel boards are used in the installation made by various panel builders and all of them may use a different brand of SPDs.

One recent example is from an installation where the transformer is protected by utility with a SPD T1 from brand A. The main panel board is protected by SPD T1 from another brand B installed by the company in charge of the external power generator. The secondary T2 SPDs are from another brand C and are located very close the main panel board as well as at various levels in the building. The last level contains a distribution board equipped with T2 SPDs brand C and some equipments running on the roof are protected by a SPD T1 from a brand D installed by the equipment supplier.

Nobody will be able to coordinate these SPDs. A solution would be to perform the coordination tests proposed by the European CLC TS 61643-12 standard. Examples of such tests are presented. An additional test that seems needed is also presented..

This paper will investigate both sides:

- application from need definition to how to use the storm detectors. This will be illustrated by real case applications.

- tests : laboratory tests as well as open air tests will be introduced

Keywords-SPDs; tests, coordination; equipment

I. INTRODUCTION

In order to protect an electrical installation the use of more than one SPD type is necessary depending on the overvoltage category of the under protection equipment and on the wiring of the electrical installation (cable length, routing etc). In this case effective SPD coordination should be examined so as not to overstress downstream SPDs but also to limit the overvoltage level to a value lower than the withstand voltage

of the under protection equipment (this new criterion is called voltage protection level criterion and is described below).

II. COORDINATION TEST DESCRIBED IN CLC TS 61643-12

A. Coordination criteria

As presented above, co-ordination of SPDs requires the completion of two basic criteria, the energy criterion and the voltage protection level criterion.

Energy co-ordination can be achieved if, for all the values of the total incoming lightning/surge current, the portion of the energy that is dissipated through the upstream SPD is higher than the energy dissipated through the downstream SPD. Additionally any elements between the upstream and the downstream SPDs should be able to withstand the same energy as the downstream SPDs. This is the basis for coordination as per today's version of the standard.

Moreover, it is additionally proposed that the voltage protection level for the downstream SPDs should be equal or ideally, lower than the upstream SPDs, since they are situated nearer to the equipment to be protected, where more precise voltage protection is required.

The most significant parameters that should be considered during co-ordination of two SPDs are the following:

- SPD types (i.e. switching type - spark gap, limiting type - metal oxide varistor);
- characteristics of the SPD type (i.e. Sparkover voltage for spark gaps, maximum continuous operating voltage for MOVs, voltage protection level, maximum discharge current capability etc.);
- injected wave (i.e. 8/20, 10/350 etc.);
- type of the equipment to be protected (i.e. heavy inductive load, sensitive electronic etc.);
- separation distance between the two SPDs.

B. Coordination techniques

Prior to any co-ordination, certain steps should be followed to select the proper SPDs and the method of co-ordination between them.

Identify the expected overvoltage level in absence of SPDs in order to select the type of SPD that will respond better. Reduction of fast overvoltages requires limiting type SPDs rather than switching type. The identification of the overvoltages should be followed by the evaluation of the maximum energy of the prospective lightning/surge current in presence of an ideal SPD. Depending on the maximum energy level, the appropriate SPD type can be selected.

Select upstream SPD according to the maximum energy so that it can withstand it.

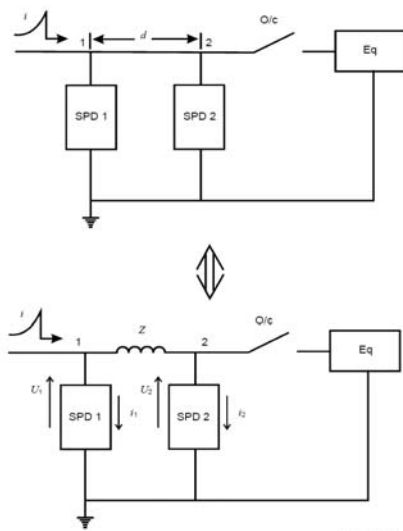
Select downstream SPD according to the desired voltage protection level of the equipment.

For the selected SPDs both the energy and the voltage protection level criteria should be satisfied. This may be done mainly with the help of software simulations or with experimental testing. In this last case the following method could be used to check this out.

C. Coordination test

Coordination between SPDs is based on current sharing. Three parameters are defined as essential in establishing a coordination rule:

- the SPD themselves (One SPD is coordinated with on other);
- the surge current at the entrance (fixed by heading SPD's characteristics);
- The decoupling impedance Z between the 2 SPDs (the heading and the downstream SPD).



Key
 Eq Equipment to be protected in normal operation
 O/c Open circuit (equipment disconnected from supply)
 i Incoming surge

Figure 1. SPDs arrangement for the coordination test

The impedance Z between the two SPDs (in general an

inductance) may be a physical one (a specific component inserted in the line to facilitate the sharing of the energy between the two SPDs) or represent the inductance of a length of cable between the two SPDs.

A SPD's coordination test can be performed by the SPDs manufacturer, by the installer or by the user.

- Coordination for SPD is achieved if these two criterions are fulfilled.
- Energy co-ordination is achieved, if for all values of surge current from a minimum testing energy to a maximum testing energy (0,1, 0,25, 0,5, 0,75, 1 time I_{max} and I_n for Type 2 SPD. 0,1, 0,25, 0,5, 0,75, 1 time I_{imp} and I_n for Type 1 SPD) the portion of energy, dissipated through SPD2 is lower or equal to its maximum energy withstand (E_{MAX2}).
- Protection coordination is achieved, if for all values of surge current from a minimum testing energy to a maximum testing energy (0,1, 0,25, 0,5, 0,75, 1 time I_{max} and I_n for Type 2 SPD. 0,1, 0,25, 0,5, 0,75, 1 time I_{imp} and I_n for Type 1 SPD) the residual voltage of SPD2 is lower or equal its declared protection level U_p .

The testing with portion of the declared I_n or I_{max} current is to explore if no blind spot up from low stress to maximum stress are existing.

D. Test settings

Coordination of various types of SPD shall be tested under coordination procedure:

- Type 1 SPD coordinated with Type 2 SPD;
- Type 1 SPD coordinated with Type 3 SPD;
- Type 2 SPD coordinated with Type 2 SPD;
- Type 2 SPD coordinated with Type 3 SPD.

E. Pass criteria

The SPD has passed the test if any follow current is self-extinguished and thermal stability is achieved after each impulse of the coordinated SPD test. Both the voltage and current records, together with a visual inspection, shall show no indication of puncture or flashover of the samples. Mechanical damage shall not occur during these tests.

The measured residual voltage of the SPD2 shall never exceed its declared U_p .

What is interesting is that this test not only determines the energy coordination but also is able to show that the protective level U_p of the second SPD is guaranteed.

F. Tests results

Type 1 SPD coordinated with Type 2 SPD from two different brands. Setting $U_c=260V$, $I_{imp}=18kA$.

Testing procedure: 0,1, 0,25, 0,5, 0,75, 1 time I_{imp} . Powered for 30 min at U_c and impulse shall be applied at 60° of the shift.

During the tests, the two SPDs were not damaged. But the

parameters U_{res} has exceeded the $U_p=1.8kV$ of SPD2. The test results show that the energy co-ordination between SPD 1 and SPD2 is successful while the protection co-ordination is not achieved.

Typical parameters of the waveform are given in Table 1

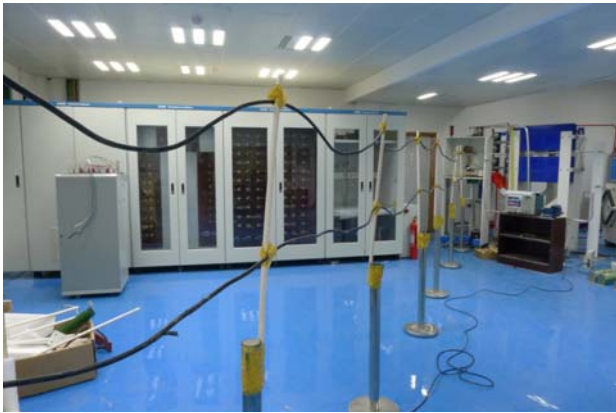


Figure 2. Loop configuration (10m)

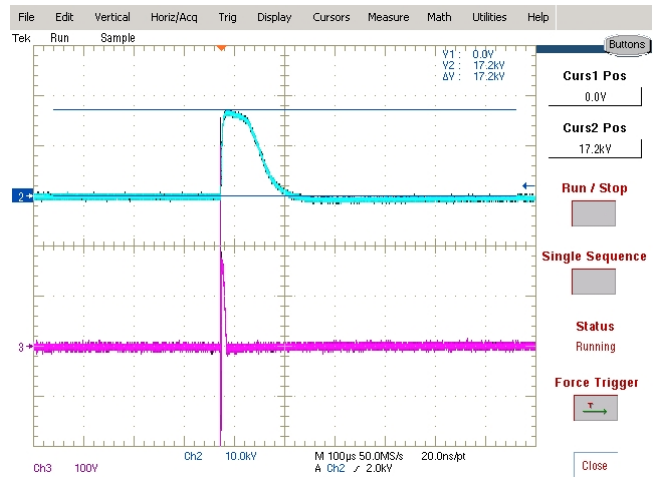


Figure 3. SPD1 and SPD2 in lab

TABLE I. TEST RESULTS.

times	I_{imp} (kA)	I_{spd1} (kA)	U_{res}	Degree ($^{\circ}$)
0.1	1.740	1.72	560	60
0.25	4.142	4.14	820V	120
0.5	8.355	8.20	1.10kV	180
0.75	12.659	12.2	1.62kV	240
1.0	17.358	17.2	2.18kV	300

Legend : I_{imp} : the impulse current from the generator.
 I_{spd1} : the impulse current through SPD1
 U_{res} : the residual voltage at SPD2 measured by differential-mode method
Degree: the phase degree of power source when triggering impulse current.



Green: Ispd1 Purple: Ispd2

Figure 4. Waveform of Ispd1 and Ispd2 with $I_{imp} = 0.1$ kA

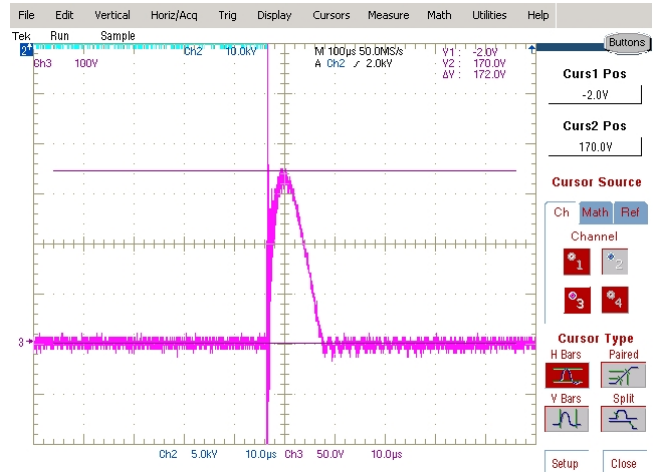


Figure 5. Zoom Waveform of Ispd2 with $I_{imp} = 1$ kA

III. ADDITIONAL TEST PROPOSED FOR BETTER APPLICATION OF SPDs

A second test would be helpful to develop: coordination with equipment to be protected. Very often SPDs need to be located near this equipment due to short protective distance (10 m seems to be a maximum for most of the equipments). In addition, a lot of these equipments have a varistor between phase and neutral to pass the EMC tests and sharing of energy between this varistor and the SPD may create serious problems. Coordination tests need then to be performed between phase/neutral an earth and between phase and neutral. It is very costly to test the coordination between an SPD and all the equipment that it may protect in practice as well as to determine the maximum allowed protective distance. In rare occasions, when the same configuration is used in many places the user or manufacturer may decide to perform real configuration tests. But very often, protection efficiency is expected and no test is made to prove it. Furthermore, the

standard says in the introduction " This standard deals only with SPDs and not with SPDs components integrated inside equipment" and later in the text "In general, oscillations may be disregarded for distances less than 10 m.. Sometimes the equipment has internal protective components (for example, varistors), that will significantly reduce oscillations even at longer distances. Care is necessary in this last case to avoid coordination problems between the SPD and the protective component inside the equipment." So it is clearly stated that internal protective component such as a varistor may degrade the sharing of energy while at the same time offering a longer protective distance but there is no way to prove it. Very often the exact equipment circuit or varistor is not known but it appears that in most of the cases the entrance impedance can fit in one of the following categories.

- Power supply through a transformer
- Power supply through a rectifier with inrush current limitation
- Power supply with power factor correction
- Power supply enabling power line communication
- All of them with or without a built-in varistor as a protective stage upstream of power supply

It is then possible to build, based on experience, typical equivalent input impedances and to test an SPD for coordination with these 4 families (and possibly sub-families as some variation may exist between the input circuit from one

equipment to another one. Altogether, less than 10 typical impedances are expected at this stage) that will give allowed protective distances to provide a) a good protection i.e. a protective voltage at equipment input circuit compatible with the withstand and immunity levels of the equipment and b) an appropriate sharing of current between the SPD and the built-in protective component.

With a limited number of tests it is then possible to give guidance to the user and to all parties (electrical engineer, panel builder, lightning risk specialist, manufacturer, laboratory etc.) about the real protective capability of the SPD when used in field.

IV. CONCLUSIONS

Coordination tests between SPDs and between SPD and typical equipment are described. Tests performed on SPDs from various brands at the Shanghai Lightning Protection Center are described and the benefits of such test are presented.

REFERENCES

- [1] CLC TS 61643-12 : Low-voltage surge protective devices Part 12: Surge protective devices connected to low-voltage power systems – Selection and application principles, 2009
- [2] Zhou Qibin, "Coordination test in Shanghai Lightning protection Center, test report, November 2011