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Experimental investigation of the coordination between SPDs and between SPD and the protected equipment☆

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ABSTRACT

Surge Protective Devices (SPDs) are widely applied to protect the low-voltage equipment against the surges from direct lightning strikes or the lightning-induced effect. To ensure the protection effect, the users should not only consider the performance and quality of the SPDs themselves, but also the coordination between SPDs and between SPD and the protected equipment. In practice, there may be SPDs with different characteristics 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. All of them may use different brands of SPDs. So it is difficult to evaluate the coordination effect between those SPDs and between SPD and the protected equipment by theoretical analysis. A solution would be to perform the coordination test. This paper provided an investigation on the proposed coordination test method for different configurations with various loads, various cable lengths, various cable enclosures and various surge waveforms through experiments in the laboratory. The sharing current and residual voltage of two cascaded SPDs were measured and discussed. The proposed coordination test method was verified to be informative for achieving successful coordination between SPDs and between SPD and the protected equipment.

1. Introduction

In order to protect an electrical installation the use of more than one SPD type is often necessary depending on the overvoltage category of the protected equipments 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 protected equipment. In recent years, the coordination between SPD has been studied with various simulation methods [1–5]. A definition of the effective protection distance was proposed in these literatures, which means the maximum distance between a SPD and the equipment to be protected, at which the SPD can suppress the overvoltage on SPD and load lower than the required safe value [2]. These researches reveal the relationship among the characteristics of SPD, the properties of the protected load and the length of the connecting cable, which can be used as an application guideline for SPD installers.

Sometimes, when SPD users need to verify the performance of selected SPDs as well as their coordination effect after installation, a testing work with real SPDs setting in laboratories is more objective and convincible than the simulation analysis. The testing method to verify the performance of SPDs is provided in IEC 61643-11:2011 [6], which is widely used for SPDs certification work around the world. But the testing method of SPD coordination effect is not widely applied and little relative study has been addressed.

This paper firstly provided an improved coordination test method between SPDs and between SPD and the protected equipment by referring to a technical specification [7]. Then an experimental investigation was carried out around three main questions associated with SPD applications, as follows,

- Question 1. The influence of the load characteristic. This will address the coordination test between SPDs and different resistive loads.

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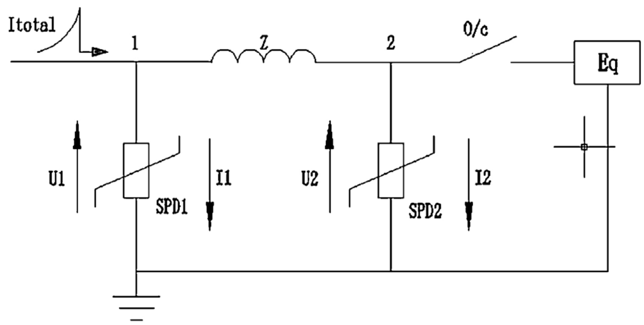

Key
Eq - Equipment to be protected
O/c - Open circuit (Equipment disconnected from supply)
SPD1 - Upstream SPD
SPD2 -Downstream SPD
I_{total} - Incoming total surge
I_1 - Current flowing through SPD1
I_2 - Current flowing through SPD2
U_1 - Residual voltage of SPD1
U_2 - Residual voltage of SPD2
Z - Impedance of the cable or decoupling components between SPDs

Fig. 1. Circuit diagram for the coordination test.

- Question 2. Influence of the cabling length and typical enclosure material around the cables. This will address the coordination test when the cables of different lengths run inside a PVC tube, inside a metallic pipe or inside a metal tray, individually.
- Question 3. The influence of the surge type. This will address the coordination test for different surges, including the steep 0.2/0.5 μs surge, the short 8/20 μs surge and the long 10/350 μs surge.

All above three questions have been experimentally investigated in the laboratory of Shanghai Lightning Protection Center in 2014.

2. Coordination test method

2.1. Coordination principle

Coordination of SPDs requires the completion of two basic criteria, the energy criterion and the voltage protection level criterion.

Energy coordination can be achieved if, for all the values of the total incoming 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 (e.g. fuses or CBs) between the upstream and the downstream SPDs should be able to withstand the same energy as the downstream SPD.

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

2.2. Coordination test method

Fig. 1 shows the test circuit of coordination between SPDs and between SPD and the protected equipment. The impedance Z, an inductance in general, between two SPDs in Fig. 1 may be a physical inductor (a specific component inserted in the line to facilitate the sharing of the energy between the two SPDs) or represents the inductance of a cable between the two SPDs.

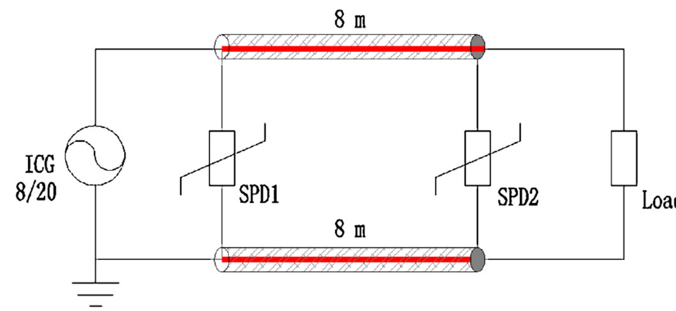

Fig. 2. Test circuit diagram with various loads.

From Fig. 1, it is noted that the coordination is based on the current sharing. Three parameters are defined as essential in the establishing coordination:

- the characteristics of the SPDs;
- the characteristic of cables between the SPDs (including impedance Z of the cable as well as the decoupling components inside).
- the characteristics of the incoming surges at the entrance;

2.3. Pass criteria

Coordination of SPDs is achieved if following two criterions are fulfilled.

- *Energy coordination* is achieved, if for all values of surge current from a minimum testing energy to a maximum testing energy, the portion of energy dissipated through SPD2 is lower than or equal to its maximum energy withstand.
- *Protection coordination* is achieved, if for all values of surge current from a minimum testing energy to a maximum testing energy, the residual voltage of SPD2 is lower than or equal to its declared protection level Up.

In addition to above two criterions, the SPD will pass 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.

3. Experiment design

3.1. Materials for experiment

- SPD:
- Load:2 Ω resistor and 55.2 Ω resistor (light bulb);
- Cable length: 8 m and 20 m;
- Cable enclosure: PVC pipe, metallic (iron) pipe, metal (steel) tray;
- Surge waveforms: 0.2/0.5 μs, 8/20 μs, and 10/350 μs;

3.2. Experimental setup

3.2.1. Coordination test with various loads

In the low-voltage distribution system, there are usually resistive loads to be protected, i.e. lights and heaters. In order to test the coordination between SPDs and these loads, two representative devices including a 2 Ω resistor and a 55.2 Ω resistor (light bulb) were chosen as shown in Fig. 3.

The coordination test circuit is shown in Fig. 2. The switching-type SPD1 in Table 1 was selected as the upstream SPD and the clamping-type SPD2 in Table 1 was selected as the downstream