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Factors affecting selection, installation and coordination of surge protective devices for low voltage systems

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ABSTRACT

The present paper aims to illustrate the influence of the main factors which affect the selection and installation of an SPD for the protection of electrical and electronic systems against overcurrent and overvoltage due to direct lightning flash to a structure. Simple rules are established for the selection of effective SPD with regard to the discharge current, its protection level and location. A comparison with the SPD requirements of international standard is performed.

1. Introduction

Electrical and electronic systems are subjected to damage from a lightning current and in order to reduce the risk of failure, protection measures have to be properly designed. Failures of such systems are mainly due to [1]:

- surges by lightning flashes to the structure resulting from resistive and inductive coupling (source of damage S1),
- surges by lightning flashes near the structure resulting from inductive coupling (source of damage S2),
- surges transmitted by lines connected to the structure due to flashes to or near the lines (sources of damages S3 and S4 respectively).

To limit transient overvoltages below the rated impulse withstand voltage of the system to be protected and to divert surge currents, surge protective devices (SPDs) as suitable protection measures are to be applied. Information for selection and installation of SPD are reported in several documents [2–7].

For a proper selection and installation of SPDs, it is of essential importance to know the stress, which an SPD will experience under surge conditions. Such stress is a function of many complex and interrelated factors such as the location of the SPD(s) within the structure, the method of coupling (resistive or inductive) of the lightning current to the system to be protected, the routing of internal circuits and their distance from inducing lightning current, the sharing of lightning current to the earthing system and to the connected services. Furthermore the different behavior of the SPD containing spark gaps (switching type SPD) and SPD containing metal-oxide varistors (limiting type SPD) is to be considered.

In the present paper only surges due to flashes to the structure (source S1), protected by a lightning protection system (LPS), are considered. The influence of the main factors and parameters which affect the selection and installation of an SPD of both types (switching and limiting) installed at entry point of line in the structure (*SPD1*) and at apparatus to be protected terminals (*SPD2*) are discussed. By several computer simulations, simple rules are established for the selection of effective SPD with regard to the discharge current and its protection level.

Comments and comparison with the requirements of the international standard IEC/EN 62305-4 are presented.

2. Case study under consideration

The analyzed arrangement is shown in Fig. 1. The investigation is focused on the influence of the installed protection devices, namely switching and limiting SPD, on the following parameters:

- peak value and shape of currents flowing through the *SPD1* and *SPD2*

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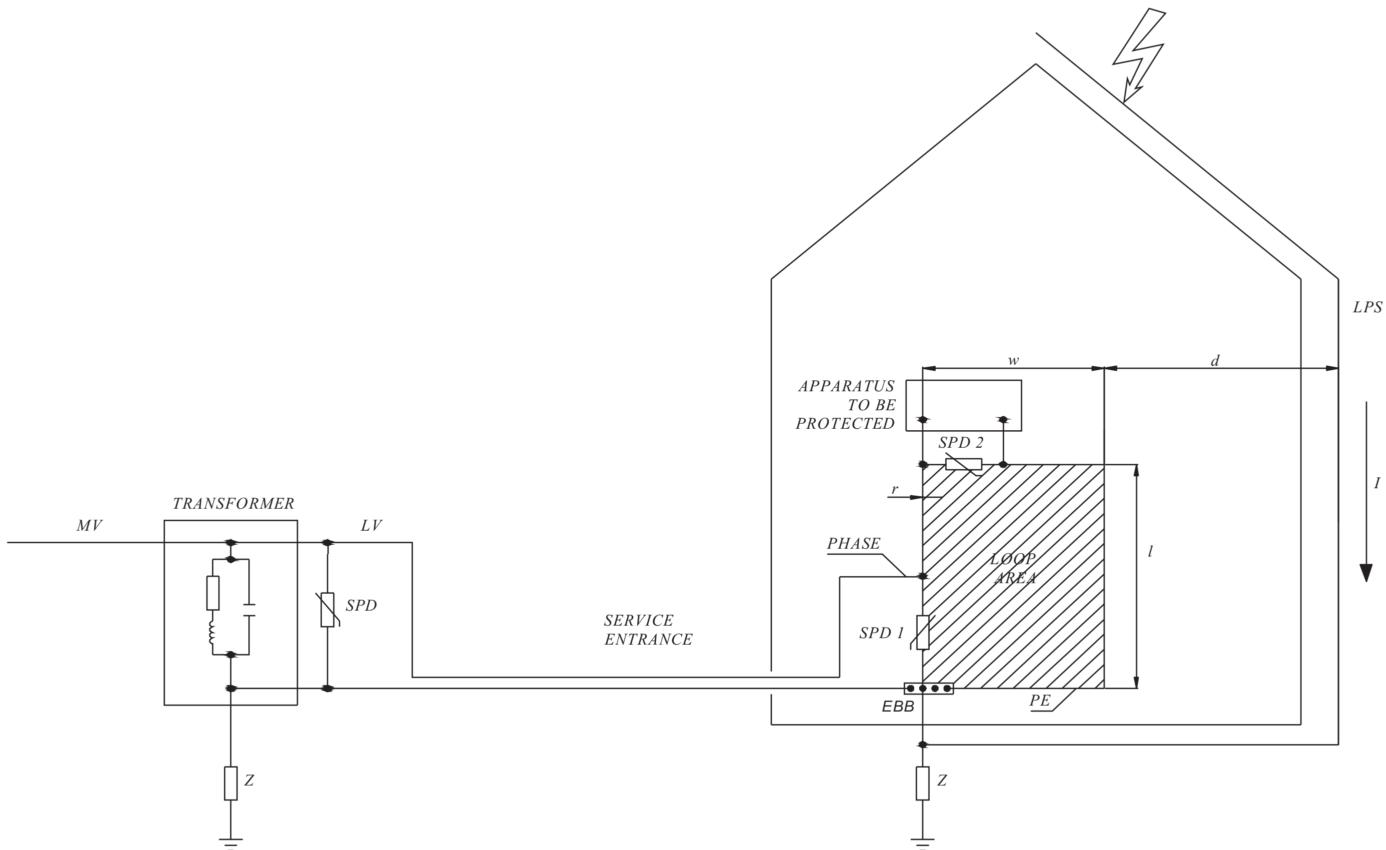

Fig. 1. Considered arrangement: lightning strokes to LPS near an electric circuit.

- charges associated to currents flowing through the *SPD1* and *SPD2*

Fig. 1 represents a simple example of flash to a lightning protection system (LPS) conductor near an electrical circuit loop, where: *I*, stroke current; *d*, distance between lightning current flowing in the electrical conductor and the induced circuit loop; *l*, loop length; *w*, loop width; *r*, wire radius; *Z*, earthing system conventional impedance; *SPD1*, SPD bonding the phase conductor to the equipotential bonding bar (*EBB*); *SPD2*, SPD at the apparatus terminals.

The analyses have been performed by means of the transient software EMTP-RV.

The lightning stroke has been simulated as an ideal current generator [8,9]. Three shapes of lightning current, namely representative of positive stroke (10/350 μs), first negative stroke (1/200 μs), subsequent negative stroke (0.25/100 μs) have been considered.

The typical low-voltage limiting type SPDs have been simulated in order to match the *U*–*I* characteristic derived by actual voltage–current measurements. SPD switching type simulation takes into account the volt–time characteristic of the spark gap and the arc resistance. The leads/connections of SPD have been simulated by means of concentrated inductance.

Supply line as well as internal circuit conductors has been simulated by means of transmission line model where the parameters typical for the usual LV cable types are inserted.

The LV/MV transformer has been simulated in transient conditions by a network representing the winding capacitance, inductance and resistance.

The transient behavior of earth termination systems of both the structure and the transformer has been simulated by means of a network of π elements consisting of a capacitance *C*, an inductance *L* and a resistance *R*. Different types of earthing arrangement, namely rod (type A according to standard IEC/EN 62305-3), ring and mesh (type B of standard IEC/EN 62305-3) have been considered.

Results of preliminary investigation on the validity of the simulation models by a comparison with experimental results obtained in HV laboratories are summarized in [10].

As reference case it is assumed:

– earth arrangement with conventional impedance $Z = 10\,\Omega$;
– a single supply line bonded to the EBB of the structure by *SPD1*;
– no other external services connected to the structure;
– lightning protection system (LPS) with only one down–conductor (current partitioning coefficient $k_c = 1$, according to IEC/EN 62305-3);
– two conductors circuit (phase and PE) feeding apparatus to be protected.

The analysis is performed on circuit with the same characteristics of the one assumed by the IEC standard 62305-1 as basic reference configuration ($d = 1$ m; $w = 0.5$ m); other induced circuit configurations are also considered, namely loop width $w = 0.1$ m and $w = 0.005$ m.

SPD1 of both types, switching (spark-gap) and limiting (varistor) are considered, while *SPD2* of limiting type only is used, as in normal cases.

3. SPD selection with regard to discharge current

The selection of the discharge current of an SPD requires the evaluation of the peak value and wave shape of the possible current flowing through the SPD [11–13]. In fact as general rule, SPD