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Impact of an extended grounding system on the factors affecting selection of an SPD system for apparatus safety

Abstract. *The influence of an extended grounding system on the dimensioning of an SPD system for apparatus protection against lightning surges is investigated. In an extended earthing arrangement, an apparatus distant from the main switch board is usually protected by an SPD system consisting of a first SPD at the main switch board (SPD1) and of a downstream SPD close the apparatus (SPD2); if the SPD2 is earthed locally, additional stresses on such SPD are expected due to lack of equipotentiality of the extended earthing arrangement. In this paper the current and the associated charge expected at installation point of SPD2 have been investigated by several computer simulations performed by means of the transient software EMTP-RV.*

Streszczenie. *W artykule rozważany jest wpływ systemu uziemienia na efektywność ochrony urządzeń, narażonych na oddziaływanie przepięć. Analizowany jest przypadek uziemienia kratowego i urządzenia oddalonego od głównej tablicy rozdzielczej, które zazwyczaj jest chronione przez system SPD składający się z: SPD w głównej tablicy rozdzielczej (SPD1) oraz SPD przy urządzeniu chronionym (SPD2). W sytuacji gdzie SPD2 jest uziemione lokalnie, występuje dodatkowe zagrożenie w związku z brakiem ekwipotencjalizacji układu uziemiającego. Przedstawione badania dotyczą spodziewanych wartości prądu i ładunku w punkcie instalacji SPD2, które zostały wykonane za pośrednictwem symulacji komputerowych przy użyciu programu EMTP-RV.* ***Wpływ systemu uziemienia na efektywność ochrony urządzeń, narażonych na oddziaływanie przepięć***

Keywords: Apparatus Safety; SPD; Overvoltages
Słowa kluczowe: Bezpieczeństwo urządzeń; SPD; Przepięcia

Introduction

The protection of apparatus against surges due to direct lightning stroke to a structure (source of damage S1) is within the scope of IEC 62305 series [1]. The information on the physical damages and life hazard provided by [2] are related to the case of the earth-termination system of structure assumed as only one earthing point and therefore considered as equipotential. This assumption fails in the case of an extended grounding system [3] or additional bonding [4], such in the case of large industrial installation.

This contribution intends to outline the problem and to provide preliminary information for dimensioning of the SPD system for apparatus protection. Moreover, to make this information useful for the update process of the standard revision, different types of meshed arrangement earthed in different soil resistivity (type B of standard IEC/EN 62305-3) have been investigated [2].

The problem was addressed by considering the following earth-termination arrangement and at the following assumptions:
- meshed earth-termination m with side meshing 10 x 10 m;
- meshed earth-termination system dimensions complying with IEC 62305-3 according to the resistivity of soil (10 x 10 m for 500 Ωm, $Z \approx 10$ Ω; 40 x 40 m for 1000 Ωm, $Z \approx 10$ Ω; 70 x 70 m for 1500 Ωm, $Z \approx 10$ Ω);
- injection point of lightning current at center (A) of meshed earth-termination system;
- circuit length between the injection point (A) and the offshoot point (B) to apparatus to be protected equal to the distance between center and edge of meshed earth-termination system.
- lightning protection level I (LPL I) values of lightning current according to IEC 62305: 200 kA (10/350 μs) for positive flashes and 50 kA (0,25/100 μs) for subsequent stroke of negative flashes.

In this contribution the current and the associated charge expected at installation point of SPD2 have been investigated.

Case study under consideration

In practice if the earth-termination system has outspread dimensions (D), the earth-termination system is no longer equipotential [5]. The analyzes are performed for a case shown in Figure 1. The SPD1 is installed at line arrival to EBB1in the main distribution board (MDB). The SPD2 is installed to EBB2 in a secondary distribution board (SDB) far from EBB1. The apparatus to be protected is connected locally to EBB2. The lightning current I on the earth-termination system from point A to point B gives rise a voltage drop ΔU_Z that circulates on SPD2 a current and an associated charge, in addition to that injected directly from SPD1 into the circuit SPD1-SPD2. In such situation SPD2, which is typically SPD of test class II, is additionally endangered.

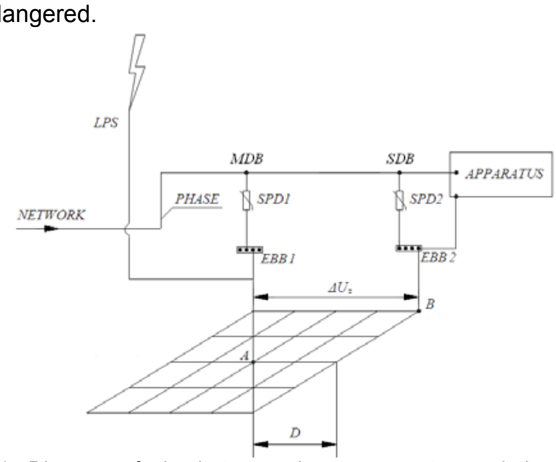

Fig.1. Diagram of circuit to supply an apparatus and the loop formed by phase conductors and two SPDs bonded to an extended earth arrangement (type B according to IEC/EN 62305-3) in different points

Several computer simulations were performed by means of well-known transient software EMTP-RV [6]. Earth termination systems of the structure has been simulated by means of a network of π elements [7] consisting of a capacitance C, an inductance L and a resistance R. The experimental results presented in [8] as well as transient software practices discussed in [9] have been taken into account. An equivalent schema of a mesh branch is shown in Figure 2. The methodology of relative parameters calculations discussed in [10] has been considered.

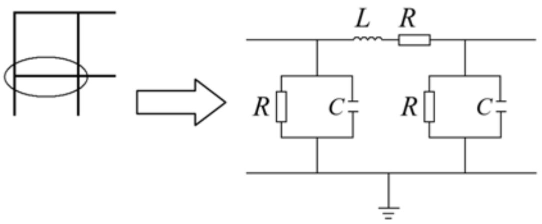

Fig.2. Simplified mesh branch model

The investigation includes both switching and limiting SPD types simulated to achieve proper characteristic voltage-ampere (U-I) and voltage-time (U-t) as discussed in [11]. The voltage protection level U_P = 1,5 kV has been assumed.

Wave shapes of lightning current, namely representative of positive flashes (10/350 μs) and subsequent stroke of negative flashes (0,25/100 μs) have been considered and simulated by the so-called Heidler function (IEC/EN 62305-1) [1].

As first approximation, soil ionization phenomena [12] that can occur when earth electrodes are injected by high pulse transient currents have been neglected.

More details on computer modelling of the specific components of the considered system are reported in [11].

Transient behavior of earthing arrangement complying with IEC 62305-3

Assuming that dimension of considered mashed earthing is equal D (m) to both sides and that it approximately corresponds to dimension r_e (m) which according to IEC 62305-3 increases with resistivity ρ of the soil, as reported in Table 1.

Table 1. Dependence of dimension D (m) ≈ r_e (m) on the soil resistivity ρ values according to IEC 62305-3

ρ (Ω m)	500	1000	1500
$D \approx r_e$ (m)	5	20	35

In such earth-termination systems, a value Z ≈ 10 Ω of the conventional earth impedance, as defined in [2], is achieved for the positive lightning flashes (waveform 10/350 μs), while a value of some tens of ohms can be reached for the following strokes of a negative lightning flash (waveform 0,25/100 μs), as shown in Figure 3.

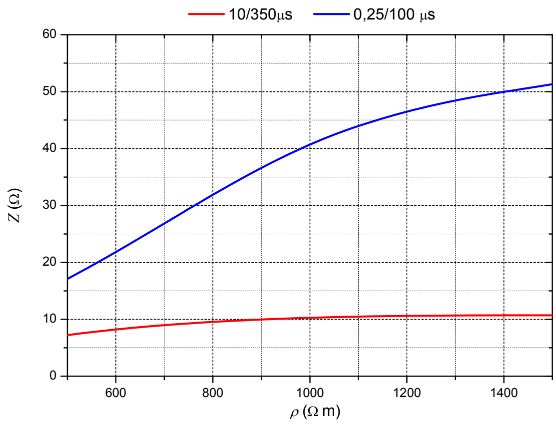

Fig.3. Conventional earth impedance Z as function of soil resistivity ρ for a meshed earth-termination system; at lightning currents relevant to LPL I

Investigation on voltages

Results of simulation show that, at the same LPL, the highest values of the voltage drop ΔU_Z between the injection point (EBB1 at center of the grid) and the apparatus to be protected (EBB2 at edge of the grid) are due to the subsequent strokes of a negative lightning flash, as shown in Figure 4.

Following the intervention of SPD1 and SPD2, the voltage drop ΔU_Z is responsible of flowing through SPD2 of a current I_{SPD2z} (and the associated charge Q_{SPD2z}) which combines with:

- the current I_{SPD2f} (and associated charge Q_{SPD2f}) transmitted by the SPD1(feeding effect) [13] and
- the current I_{SPD2i} (and associated charge Q_{SPD2i}) induced by lightning in the loop circuit formed by the phase conductor and the two SPDs (inducing effect) [14].

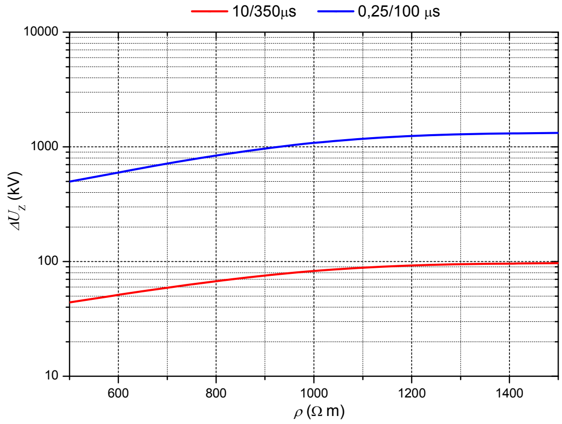

Fig.4. Voltage drop ΔU_Z between the center and the edge of the grid complying with IEC 62305-3

The latter two currents (and associated charges) would still be present even if the earth-termination system was equipotential.

For the correct selection of SPD2 it is necessary to know the amplitude and the waveform of the whole current I_{SPD2} (as well as the charge associated Q_{SPD2}) expected at SPD2 installation point.

Investigation on currents and associated charges

From the installation point of view the worst case consists of EBB1 connected at center of the grid and EBB2 at edge of the grid. The results in such case are shown in Figure 5 and Figure 6, at the same protection level LPL I for current I_{SPD2z} and charge Q_{SPD2z} respectively. With reference to the current due to the voltage drop ΔU_Z, the highest values of I_{SPD2z} and related associated Q_{SPD2z} occur for the lightning positive flashes.

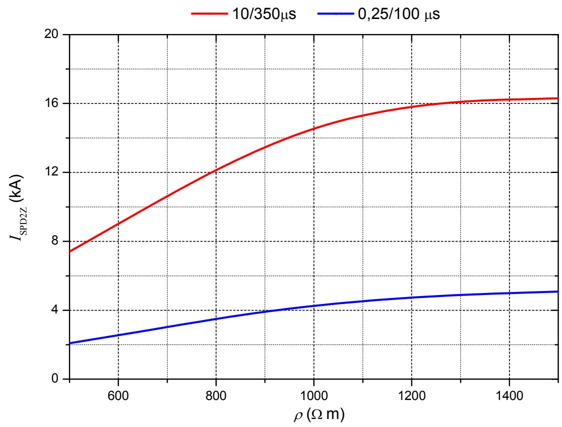

Fig.5. Current I_{SPD2Z} in a circuit with SPD at both ends for a meshed earth-termination system complying with IEC 62305-3; at lightning currents relevant to LPL I

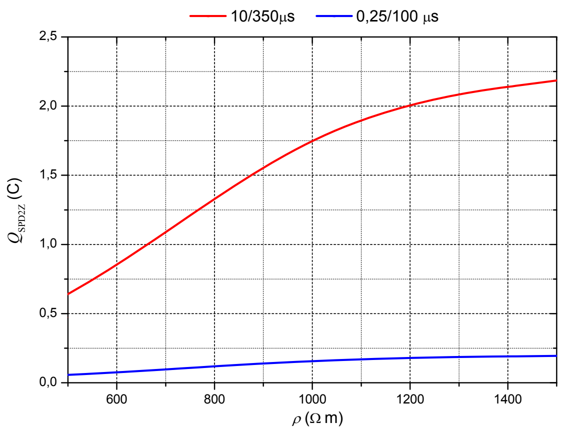

Fig.6. Charge Q_{SPD2Z} associated to the current I_{SPD2} in a circuit with SPD at both ends for a meshed earth-termination system complying with IEC 62305-3; at lightning currents relevant to LPL I

The values of current I_{SPD2z} and of associated charge Q_{SPD2z}, shown in Figure 5 and Figure 6, ranges between 7,5 ÷ 16 kA and 0,7 ÷ 2,2 C respectively according to the soil resistivity; then they are of the same order of magnitude or even more of the currents (I_{SPD2f}, I_{SPD2i}) and charges (Q_{SPD2f}, Q_{SPD2i}) on SPD2, relevant to the case that the earth-termination system is equipotential or that the apparatus is bonded at the same equipotential bonding bar of the main distribution board (MDB) where the SPD1 is installed.

In fact, in such case, as reported in [13,14], according to the type of SPD1, switching or limiting, for LPL I the following values for SPD2 dimensioning can be postulated:

a) in the case of SPD1 of limiting type:

- a combined charge (Q_{SPD2f} and Q_{SPD2i}) ranging from 2,8 to 1,4 C;
- a combined current (I_{SPD2f} and I_{SPD2i}) ranging from 11 to 7,5 kA;

b) in the case of SPD1 of switching type:

- a combined charge (Q_{SPD2f} and Q_{SPD2i}) ranging from 0,04 to 0,25 C;
- a combined current (I_{SPD2f} and I_{SPD2i}) of the order of 1,5 kA.

Conclusions

On the base of performed analyses, the following conclusions can be formulated:

- in an industrial plant of great extension where the earth-termination system is no longer equipotential and typically the apparatus to be protected are bonded to an EBB2 different from the EBB1 of the main distribution board, it is not possible to neglect the stress due to the potential differences between the different EBB;
- in selection the downward SPD (SPD2) these stresses should be also considered and combined with those due to the feeding effect by the first SPD (SPD1) and to the inductive effects produced by lightning current in the circuit between the SPD1 and SPD2;
- as SPD1 and SPD2 must withstand the charge flowing through them, and the protection level U_p of SPD2, in correspondence to the current flowing through it, must not be greater than that required for the protection of the equipment, the SPD system, designed for equipotential earth-termination system, may be undersized when used for extended grounding system.

These conclusions may be useful in the frame of the international standard revision and in particular in the correct selection of SPD system to reduce the damage of an apparatus with a given probability.

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