

Lightning Protection System taking into account currents greater than IEC 62305 standardized values

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Abstract— For few facilities such as nuclear sites, it is important to take into account stresses that may exceed usual ones. As a matter of fact, Fukushima event has shown that natural stresses greater than average should be considered. Obviously this doesn't apply to all nuclear facilities and in a specific nuclear facility this will not apply to all structures and equipment but only to a few of them that are nuclear basic safety equipment (BSE) or basic safety structures (BSS) as defined by national authorities or by nuclear operators. In nature, lightning current parameters may exceed values fixed by standards both ways: current can be as high as 300 kA and current can be as low as 2 kA. Damages coming from such low current on buildings are not expected to be high but they can interact with sensitive equipment that are necessary for the safety the installation. Experience feedback also shows that for multiple applications there should be an interest to address other values than standardized ones..

Keywords— Lightning; nuclear; CIGRE; testing

I. INTRODUCTION

For few facilities such as nuclear sites, it is important to take into account stresses that may exceed usual ones. As a matter of fact, Fukushima event has shown that natural stresses greater than average should be considered. Obviously this doesn't apply to all nuclear facilities and in a specific nuclear facility this will not apply to all structures and equipment but only to a few of them that are nuclear basic safety equipment (BSE) or basic safety structures (BSS). Such nuclear basic safety means (BSM) are defined by national authorities or by nuclear operators. Lightning is one of the stresses to be studied for these BSM. In nature, lightning current parameters may exceed values fixed for level of protection I. For example, level of protection I defines a magnitude of current between 3 kA and 200 kA. These values may be exceeded both ways: current can be as high as 300 kA and current can be as low as 2 kA. Then it is really necessary for such BSM to know what can be the influence of these currents either greater or lower than defined for level of protection I. The paper present an ongoing project preliminary applied to a real

structure being a BSS in a nuclear site. It may apply to others in near future. It follows a previous theoretical study performed to determine what should be the key parameters to use for designing a lightning protection for such a building that should be able to operate in spite of very severe storms.

II. THE CONSIDERED LIGHTNING STRESS

A. IEC 62305-1

Probabilities associated to currents as high as 300 kA are given in IEC 62305-1 [1]. In current Edition 2 of the IEC 62305-1 standard, values as high as 600 kA are even listed in Annex A (see Fig. 1). Lightning current above 300 kA have never been measured, and accordingly Edition 3 of the standard (not yet published) will not keep these values of current greater than 300 kA. Greater values than 300 kA are sometimes announced but they are not really measured. They are derived from Lightning Location System data. For the present study, a maximum current of 300 kA has been considered. Probability associated to 300 kA is 0,005. Other parameters associated to these low probabilities can be derived from curves and table given in IEC 62305-1. IEC 62305-1 is based on ELECTRA [2], [3] parameters that have been largely confirmed by a recent CIGRE report [4]. Parameters that are pertinent for lightning and surge protection are, in addition to the peak current, impulse charge and total charge, as well as di/dt. We need then to consider a first impulse with a 300 kA peak value followed by a continuous current and a subsequent impulse with high di/dt.

Lightning current I [kA]	Probability P
200	0.01
300	0.005
400	0.002
600	0.001

Fig. 1. Probability of lightning current peak values according IEC 62305-1.

B. Fixed parameters

In order to cover the most severe stress a direct lightning current was fixed for that project: a first impulse (300 kA 10/350 wave shape) followed by a continuous current (500 A, 0,5 s) and a subsequent impulse (50 kA, with a front of 200 kA/ μ s). This will be named the Specific Lightning Current stress (SLC).

C. Reality check

Damages on Lightning Protection Systems have been observed in field on systems installed and tested according to standards. This means that current greater than 200 kA are occurring. As discussed above, current greater than 300 kA are sometimes announced to justify the failure of the Lightning Protection System but the current magnitude is not measured but just derived from Lightning Location Systems. In any case, even if the current is not as high as announced, current between 200 kA and 300 kA are clearly occurring and damages observed accordingly. In addition, multiples strikes are more and more involved in damages on Surge Protective Devices. Specific generators have been developed in China to cover such a case and investigations have shown that multiple surges were one of the main causes to explain SPD failures encountered in the field [5], [6].

III. APPLICATION

A rather simple building, dedicated to the site rescue team, which is classified as BSS, has been used as a preliminary step for applying such a high SLC stress. This building is made of concrete and has a rather simple shape. The building has to meet the esthetics rules of the nuclear site and is designed to withstand the severe stresses coming from wind and earthquake. This building is presently at the design stage.



Fig. 2. Building used for the study.

Even if the whole structure needs to be protected at level I, only a few points on the roof can be impacted by the extreme lightning current considered for that project. Regarding extreme current in the range 200 kA up to 300 kA the rolling sphere model (RSM) has been used to determine the point of the structure (roof) that could be impacted. This rolling sphere should cover lightning current between 200 kA and 300 kA and is then determined for the magnitude of 200 kA. At the end of this process, lightning rods were located on the roof to protect the building locally against huge lightning currents. Then the rolling sphere model was used again to check that the structure was well protected at this level of current. It should be noted that in that case, we have to consider positive strikes when in general the RS applies to negative strikes [7].

Additionally, a rolling sphere corresponding to level I of protection was also used to determine how to protect the building with regular protection means at level I of protection. Locations on the roof that need protection at level I, have been identified. Protection is then provided by a mix of striking roof and mesh system. At the end, a third rolling sphere was used corresponding to the minimum current of 2 kA to check that no external equipment could be impacted by lightning (light, vents, sensors ...). Whenever needed a specific protection based on additional striking rods has been used to protect the external equipment that could have been impacted with this low current. Once again, purpose is to ensure that nothing will disturb the building operation in stormy periods.

Extreme wind pressure was a specific constraint to take into account for the rods design. For the 200-300 kA range of current, the main target has been to split the extreme current as soon as possible such as the current flowing in downconductors be compatible with level I of protection (i.e. not greater than 200 kA). This was especially critical as the down-conductor needed to be embedded in the concrete. At least 3 paths of same length need to be used to connect the lightning rods to down-conductors to ensure that current in down-conductors never exceed 200 kA.

As soon as the lightning protection on the roof was determined it was necessary to determine the location of down-conductors and the earthing system. Natural component were used inside the concrete walls as down-conductors. Inside the concrete, the equipotentiality between down-conductors, apron and wall iron framework was studied with precision. Penetration of the current inside the wall was specifically studied as well where current exits the wall to reach the ring earthing electrode. The rebars were soldered at different layers in order to form a mesh and in addition a copper conductor was also integrated inside the concrete.

All components used for the LPS (Lightning Protection System) either inside or outside of concrete are in accordance with the standard IEC 62561 series [8]. Where the current is not yet reduced by multiple sharing, this means near the 300 kA impact point, lightning rods, copper conductors and exothermic welds have been used. Purpose was to reduce the current enough before entering the concrete to meet level I characteristics. Of course, specific tests are needed for these components located on the roof.

At the grounding level the current 300 kA is also to be considered. Near injection point in the soil, in addition to the ring earthing electrode (Type B according to IEC 62305-3 [8]) around the building, additional earth electrodes (Type A as per IEC 62305-3) were used to facilitate the current flow in the rocky soil. To avoid problems for the people being in vicinity and for equipment inside the building, the earthing system must have the lowest possible impedance. This impedance will be considered for the rating of the Surge Protective Devices

Separation distance was calculated near the lightning protection system above the roof with the specific impulse current of 300 kA. The higher current leads to greater voltage and thus to greater separation distance. However, there were limited equipment on the roof and it was easy to keep them apart of the rods. At down-conductor level, there is no more separation

distance to consider as down-conductor are equipotentially bonded to rebars.

Protection of people near the lightning protection earthing system has been also specifically addressed to take care of the 300 kA impulse current flowing in the earthing system.

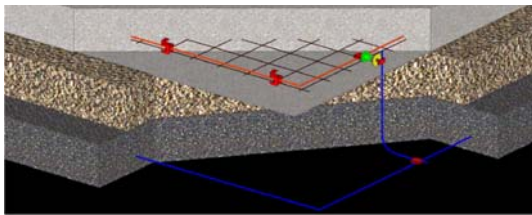


Fig. 3. Typical example of down-conductors inside the reinforced concrete

Global equipotentiality was used at ground level for all metallic pipes entering the structure. The sharing of current between the pipes and the power lines was estimated to design the size of the bonding elements including Surge Protective Devices. SPDs Type 1 have been defined on all incoming lines (either power [10] or data lines [11]). The building is supplied by a power line and an external power generator. There are two telecom/data/signal lines connected to remote telecom switches allowing the rescue team to obtain data for the whole site from the BSS building. The power lines should be protected such as they don't leave big surges entering the structure. Regarding the telecom/data/signal line they should be operational all the time. The disconnectors on power SPDs were determined to have the same surge withstand than the SPD itself. Rating for the SPD was defined by using the 300 kA impulse as well as the continuous current and taking care of the earthing system current dissipation. Only a partial current if flowing through SPDs.

Protective level provided by this SPD should be defined by taking into account a 200 kA/ μ s impulse: this has influence on the SPD itself that may have an inductive behavior and on the lead conductors (impacting the usual 50 cm rule). This means that specific tests need to be performed.

Of course, in such conditions, the effective voltage protection level will be quite high and it is difficult to provide adequate protection with a single SPD. Further SPDs will be necessary downstream to protect specific sensitive equipment. Coordination rules must then be checked with the SLC stress. This can be done by testing or by simulation based on raw data provided by the SPD manufacturer.

IV. CONCLUSIONS

To study lightning risk for Nuclear Basic Safety Structures of nuclear facilities, a new methodology was developed to take care of extreme lightning currents based on IEC 62305-1 standard. This particular method takes into account a Specific Lightning Current stress which is more severe than the usual lightning protection I (first impulse of 300 kA 10/350 wave shape followed by a continuous current and a secondary impulse with a high di/dt). In standards lightning protection systems, highest current than defined for level I of protection are not considered. In the same way the effect of continuous current on equipment is not investigated. In addition, the fact that lower currents than defined for level I of protection can strike the building are ignored by definition of the level of protection. Damages coming from such low current on buildings are not expected to be high but they can interact with sensitive equipment that are necessary for the safety of the installation.

This paper is based on a preliminary simple building on an ongoing project. This preliminary building is still at the design stage.

To protect the building from direct strikes, the strategy is mainly based on natural components. Components used either in concrete structure or above the roof will be tested in an European laboratory with the defined Specific Lightning Current stress. Surge Protection Devices will be also tested and the coordination between the equipotential bonding SPDs at the entrance and the secondary SPDs to protect sensitive equipment will be demonstrated based on tests and simulations.

Once the availability of needed components will be demonstrated by specific tests, the same method should be applied to more complex buildings.

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