

Step voltage nearby tree for surge current excitation

Abstract. Step voltage situation arise when it is possible for a person to make simultaneous contact with a part of an electrical system which is not live under normal conditions but has become live due to the passage of current for example lightning strike one. The purpose of this paper is to provide knowledge about the levels of step voltages around tree without lightning protective system during direct lightning stroke to it. Step voltage measurement results were presented for maple tree. High voltage surge generator were used as an excitation source (37kA, 8/26 μ s).

Streszczenie. Różnica potencjałów na powierzchni ziemi determinuje powstanie napięć krokowych. Bezpośrednie wyładowanie piorunowe w drzewo może spowodować ich powstanie. W tym artykule zaprezentowano wyniki pomiarów napięć krokowych, które powstały przy przepływie prądu udarowego przez Klon Zwyczajny. Jako źródło wymuszające wykorzystano wysokonapięciowy generator prądów udarowych - 37kA, 8/26 μ s. (Napięcia krokowe w pobliżu drzewa przy wymuszeniu w postaci prądu udarowego).

Keywords: step voltage, lightning, measurements, maple tree.

Słowa kluczowe: napięcie krokowe, wyładowanie piorunowe, pomiary, klon zwyczajny.

Introduction

The direct lightning strike to tree not equipped with lightning protective system (LPS) can be dangerous for the people standing nearby it. Transient step voltages can arise on the ground surface due to surge current injected into the soil by the earth electrode which in this particular case can be tree trunk and tree roots. There isn't much information about the life hazard caused by transient electric stress on human being.

As well known ventricular fibrillation is caused when an electrical stimulus of sufficient strength strikes the heart in the vulnerable period. This period which is represented in the electrocardiogram by the T-wave, is characterized by a non-homogeneity or differences in the refractoriness of the heart fibres. Only then can fibrillation be initiated, and it is self sustained by cyclic excitations. Fibrillation of the ventricles (the main pumping chambers) is accompanied by a loss of coordinated muscular contraction and the heart muscle quickly becomes exhausted and, if the condition is not soon corrected, an irreversible standstill of the heart occurs [1, 7].

Measuring situation description

Step voltage level is strictly correlated with tree root system. Situation is similar to grounding system case. Most tree roots do not penetrate very deeply into the soil. Unless the topsoil is bare or unprotected, trees will concentrate most of their absorbing roots in the top 15 to 45 cm of soil, where water, nutrients, and oxygen can be found. Tree root systems cover more area than might be expected - usually extending out in an irregular pattern 2 to 3 times larger than the crown area. However, on a dry weight basis, the "root to shoot" ratio is around 20 to 80%, making the top four to five times heavier than the roots. The type of roots formed initially is specific to a given species with age the initial root form is often modified by the growing environment. Such thing as soil hard-pans, water tables, texture, structure, and degree of compaction all influence the mature root form. There are three basic classes of tree root systems:

- tap root (for example: hickory, walnut, butternut, white oak, hornbeam),
- heart root (for example: red oak, honey locust, basswood, sycamore, pines),
- flat root presented on figure 1 (for example: birch, fir, spruce, sugar maple, cottonwood, silver maple, hackberry).

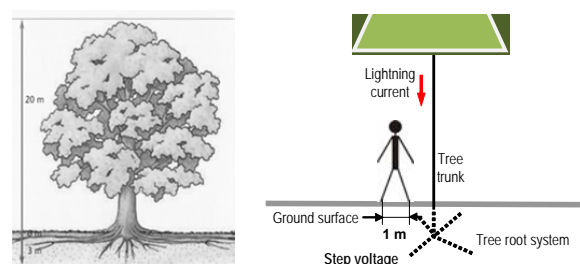


Fig. 1. Maple flat tree root system and transient step voltage measurement method.

In small park for the measurements purpose maple tree were selected. Maple tree should create worst case with respect to step voltage level because flat root system. On figure 2 were presented photo taken during measurements.



Fig. 2. Step voltage measurements in progress

The step potential is defined as the potential difference between a person's outstretched feet, normally 1 meter apart – figure 1, without the person touching any earthed structure [4] – human worst.

For the purpose of circuit analysis, the human foot is usually represented as a conducting metallic disc and the contact resistance of shoes, socks, etc., is neglected [4]. Traditionally, the metallic disc representing the foot is taken as a circular plate with a radius of 0,08 m. A value of 1000 Ω were used as a resistance of a human body from one foot to the other foot [4]. During the measurements voltage electrodes dug on 0,08m depth represents human foot.

Arrangement during the step voltage measurements presents figure 3. High voltage generator were connected to the maple tree by copper ring. Ring were installed on 1,3m height from ground level. Current loop were closed by four additional current electrodes putted on square traverse. High voltage generator produced 8,4/26,4 μ s current surge

with $I_{max}=37kA$ [8]. Current waveform presents figure 4. Generated surge current forces step voltages nearby the tree.

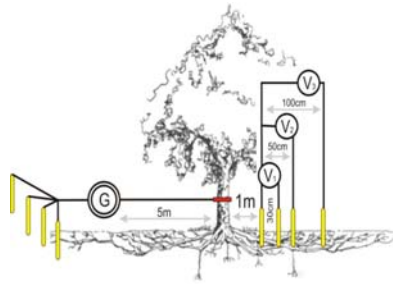


Fig. 3. Arrangement of step voltage measurements – front view

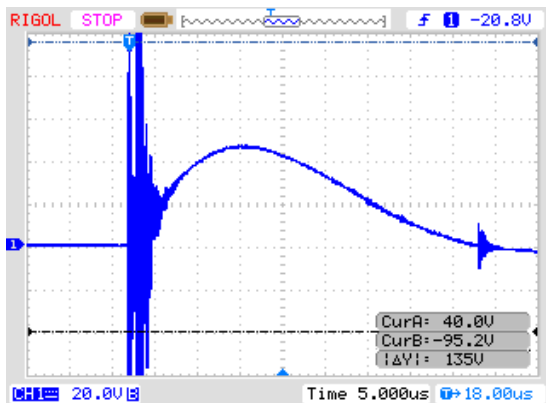


Fig. 4. High voltage surge generator output current

All recorded waveforms were presented on figure 5 and 6 for different time window. Maximal value depends on time moment. In first microseconds step voltage have got negative polarization and reaches 4kV for smallest foot distance. This voltage jump is strictly correlated with high voltage generator. At time $t=0\mu s$ internal capacitors were connected to output by triggering mechanism. This forces high voltage level at nearby $t=0\mu s$ time. It seems possible that voltage level during real lightning strike can reach millions volts. This phenomenon will be analyzed in future time [9-14].

At fourteen microsecond step voltage have got positive polarization and reaches 2,8kV for 100cm foot distance.

Conclusion

In order to ensure the safety of people at a open area, it is necessary to ensure that step potentials in and around the yard during lightning conditions are kept below set limits. These maximum permitted step potentials are addressed within various national and international electrical standards. The results of measurements of lightning transient step voltage distributions in an around a tree in case of direct lightning stroke to it were presented above. Observed step voltage exceed two times safe level according IEEE Std 80-2002 [3]. Main factor which determine step voltage distributions were different tree roots classes. Trees such as birch, fir, spruce, maple, cottonwood, silver maple, hackberry and they root system provides highest step voltage levels.

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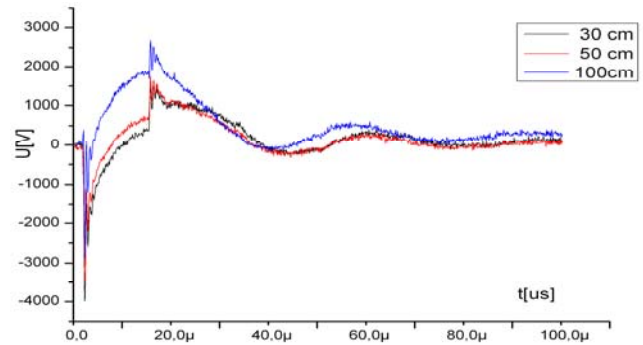


Fig. 5. Step voltage nearby tree – view for $t \in <0;100>\mu s$

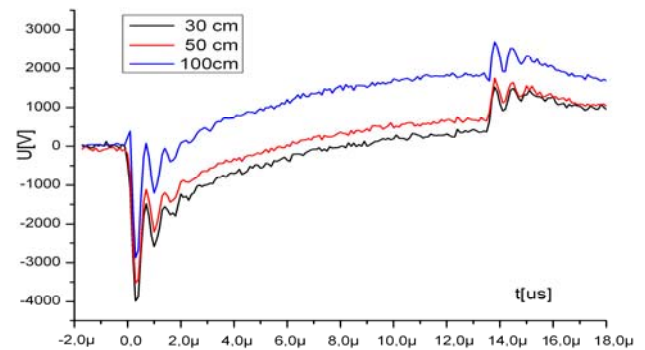


Fig. 6. Step voltage nearby tree – view for $t \in <0;18>\mu s$

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