The Impact Of ESD From Corona Discharges On The Human Body: A Computer Simulation

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***Abstract*—It is of interest to understand the impact of electrostatic energy, originating from corona discharges, on the human body. In this paper, computer simulations are performed in order to extract estimates of the dynamic currents and voltages that might be experienced by a user of electronic equipment in which sources of corona discharges might be present in the equipment, and in which the corona discharges into the human body. The model is extracted from previously published work, however, the author extends this work to include corona discharges that propagate from the finger tip of a human's hand, then through the torso of the body, and then finally through the finger tip of the other hand to which the electrostatic energy returns to its source. This model includes the worst case situation in which the full extent of the energy from the corona discharge propagates throughout the entire body before returning to its source. It is the intent of this paper to provide clinical engineers with data that might facilitate an understanding of the effects of this class of electrostatic discharge on the human body.**

I. Introduction

Some industrial equipment contain sources of corona discharges that might be encountered by service personnel who service this equipment. Given the potentially large magnitudes of electrostatic discharges from the source of the corona, it is of interest to understand any potential health issues with respect to the situation in which the discharge propagates throughout the entire human body before returning to its source. Electrostatic discharges from coronas can be very large, and can reach as high as about 20kV in their magnitudes. Figure 1 shows the scenario in which such a discharge first enters a human's finger on one hand, and then propagates through the human's arm, followed by the torso, and then finally exits out of a finger from the other hand before returning to its source.

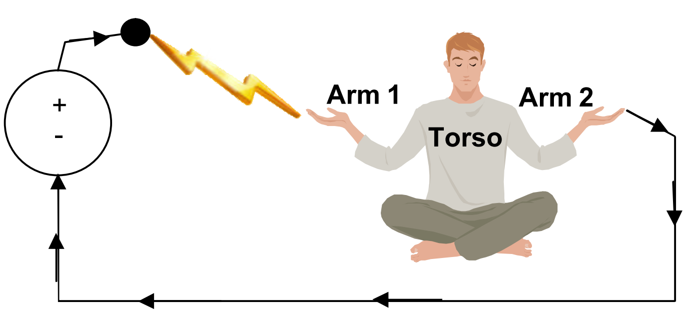

Fig. 1. Conceptual drawing of a corona discharge propagating through the human body, finger tip to finger tip, before returning to its source.

II. Simulation Results

The electrical circuit for modelling the situation in Fig. 1 is shown in Fig. 2. In this case, the arm in which the corona discharge enters the human body is modelled as the group of elements indicated by the term "Arm 1". Similarly, the torso is modelled as the group of elements indicated by the term "Torso". Finally, the arm in which the discharge from the corona exits and then returns to its source is denoted by the group of elements with the label "Arm 2".

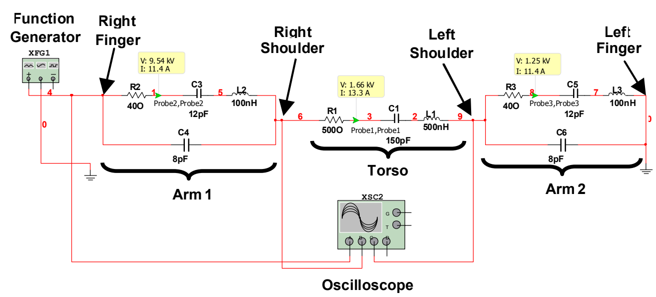

Fig. 2. Electrical schematic for modelling the situation shown in Fig.1.

The circuits that represent the two human arms are characterized with a series connection of a 40Ω resistor with a 12pF capacitor and a 100nH inductor. In parallel with this series connection of elements is a 8pF capacitor. Together, these elements model each human arm. The values of these components were obtained from previously published work [1]. The human torso is modelled by the series connection of a 500Ω resistor with a 150pF capacitor, as well as a 500nH inductor.

Since it is assumed that a worst case condition exists in which the discharge from the corona travels throughout the entire human body, there is no return path back to source prior to exiting the second arm (Arm 2). Current and voltage probes, as well as an oscilloscope, were placed in the circuit in order to extract the dynamic voltages and currents that exist in the circuit. Figure 3 highlights the various voltage waveforms that were displayed on the oscilloscope.

Figure 3 shows the voltages associated with the right finger tip, the right shoulder, as well as the left shoulder. In this simulation, the corona discharge, modelled by the function generator, was assumed to be characterized with a voltage amplitude of 10kV, a risetime of 1ns, and a duration of 60ns, which are all typical parameters associated with corona discharges. Note how Fig. 3 shows that the right finger and right shoulder take the brunt of the corona's discharge. In this case, the maximum voltage induced on these body parts is equal to the 10kV discharge level. On the other hand, the maximum voltage induced on the left shoulder is about 5kV. Once the discharge into the human body has reached 0.0V, the body continues to experience some residual effects. For example, the voltage on the right arm (Arm 1) momentarily experiences a negative voltage level equal to about -4.8kV. Eventually, the voltages induced throughout the body reach a 0.0V level after about 15ns after the end of the discharge from the corona.

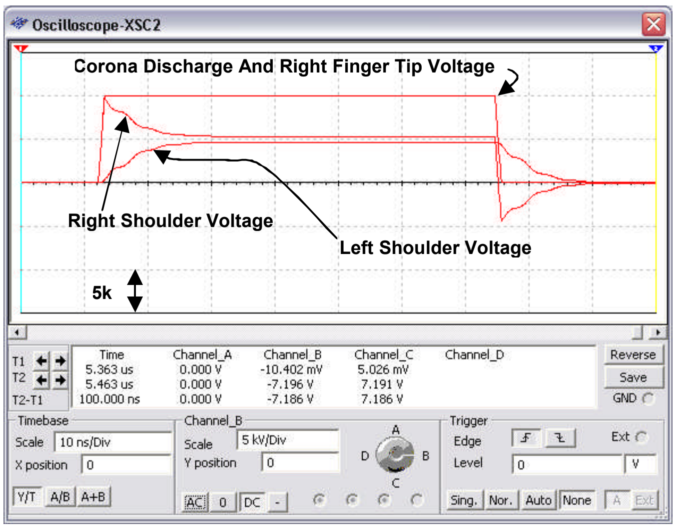

Fig. 3. Voltages present from the circuit shown in Fig. 2.

The maximum current level that propagates throughout the human body as a result of the 10kV discharge from the corona was shown to be about 13.3A, a rather large value. However, the time duration of this current level is on the order of a few nano-seconds. It is interesting to note that a sustained voltage level of about 5kV is experienced by the human body for most of the duration of the discharge from the corona, which results in a current level of about 6A throughout the body for about 50ns. It is expected that this level of current and its duration can cause momentary moderate to severe pain. The energy from the 10kV discharge was estimated to be about 10mJ. Of course, stronger discharges from the corona will cause higher current levels and higher energy levels. Given the results from the simulations of typical discharges from coronas, equipment containing sources of coronas that might discharge onto a human body should not be allowed to do so, based upon the expected temporary moderate to severe pain threshold that might be experienced by service personnel, for example.

III. References

[1] *Electromagnetic Compatibility Handbook*, Kenneth L. Kaiser, CRC Press, Chapter 27, pages 119-120.