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Electromagnetic Interference from a Lightning Impulse Generator

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ABSTRACT: Impulse voltages are generally generated by storing a level of energy in a system and then discharging suddenly. For the discharge process to take place, fast switches have to be used. Commonly gap switches, at most spherical gaps are used for switching. In high voltage applications, these switching processes produce electromagnetic fields. Sensitive devices can easily become the victim of these interferences. In this study, electric field measurements for a spherical gap switch are evaluated. Gap switch is chosen without a case and gas tube, thus simply the bare spheres are evaluated.

Keywords: Impulse generator, spherical gap switch, interference, E-field, transient.

I. INTRODUCTION

High voltage switching operations and discharge phenomena in a gas gap cause electromagnetic transients. These transients radiate high electromagnetic fields of high frequency and cause interference to sensitive electronic equipment as oscilloscope, voltmeter and PC. For example, the environment of most concern is those of high voltage laboratories and high voltage switchgears. The magnitude of radiated fields can be significantly higher than those specified in relevant immunity standards. As a result, the immunity level of sensitive equipment may not be sufficient in the environment described. At high interference fields, appropriate measures will be required for sensitive equipment. Appropriate measures can be taken if the magnitude-frequency spectra of radiated interference are available or are predictable.

High voltage impulse generation is very important for testing in laboratory conditions. For this purpose, a single stage Marx generator is designed and constructed [1]. The generator simulates the lightning impulse voltage and has a standard front time and time to half value of 1.2 / 50 µs. The main aim was to perform some tests on the circuit components, change the voltage levels, alter the rise - fall duration and evaluate the different switches. For this aim, it's decided to have a reasonable nominal output voltage as 12 kV peak level and a low energy level as 10 W. Components used allow generating lightning impulses up to 18 kV [2].

Air gap switch used was a pair of sphere made of brass, with a diameter of 15 mm each. The study is intended to state e-field radiation caused by arcing, give some data for environments containing sources of arc. Discharge process on spherical gap causes a wideband transient effect. This transient effect brings many problems for susceptible systems like electronic devices, micro electronic components.

The paper presents measurements of electromagnetic fields radiated from the spark gap of a high voltage impulse generator.

II. MEASUREMENT PROCEDURE

The circuit of the single stage Marx generator is given in Figure 1 [1]. The generator circuit was fed by a high dc voltage source adjustable from 0 up to 25 kV. Measurements are performed in two different environments. First the setup was arranged in a shielded room. Then a full anechoic chamber was used not to have any effect of the reflections.

C_1 = 150 nF, C_2 = 4.7 nF, R_1 = 490 Ω and R_2 = 100 Ω.

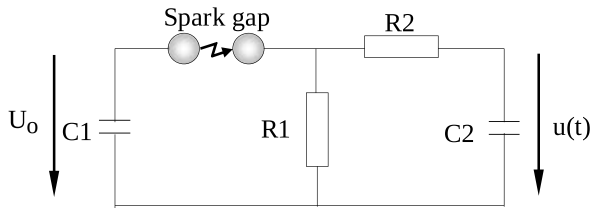


Figure 1. Generator circuit used for measurement.

Setup for the measurement is given in Figure 2. Generator circuit is laid on a plane, 1 m above the ground level. To receive the field, biconical antennas of Schwartzbeck were used. Received transient field signals were scoped using Agilent Tech. Infiniium, an oscilloscope with a sampling rate of 4 Gsa/s. In order not to have an unwanted situation, different attenuators for high levels of output were used before the input port of the scope. Connection between the antenna and the oscilloscope was made with coaxial RF cable.

A. Shielded Room Measurement

To see the effect of the reflecting waves, measurement setup was arranged in a shielded room. The room has dimensions of 2 x 2.5 x 2.5 m (W x L x H). All four walls, the floor and the ceiling dyed with conductive copper dense paint, the door gasketed and shielded, and properly grounded.

Impulse circuit with spherical gaps were set on a isolative material of 5 cm thick, which laid 1 m above the floor level, on a copper plane of 1 x 1.5 m. Biconical antenna was set to 1 m distance from the circuit and 1 m above the floor. The hvdc source and the oscilloscope were left out of the room to have a better control and scope, and also not to effect the measurement.

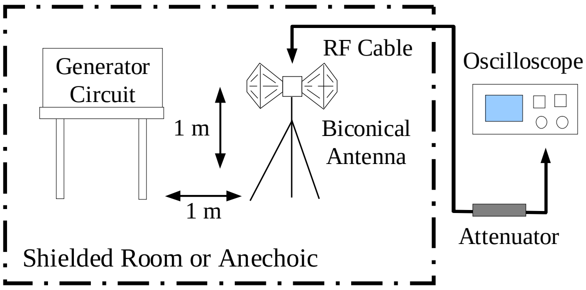


Figure 2. Measurement Setup

Changing the gap distance of the spheres each time, hvdc sources output is raised slowly until a breakdown took place. Thus different levels of voltages are obtained and the gap intervals in mm, voltage level for the breakdown in kV were noted. Also the output of the scope and the data of the transient were saved. For all the measurements performed in the shielded room, an attenuator of 12 dB was used for the input port of the oscilloscope. An example waveform for the shielded room is given in Figure 3.

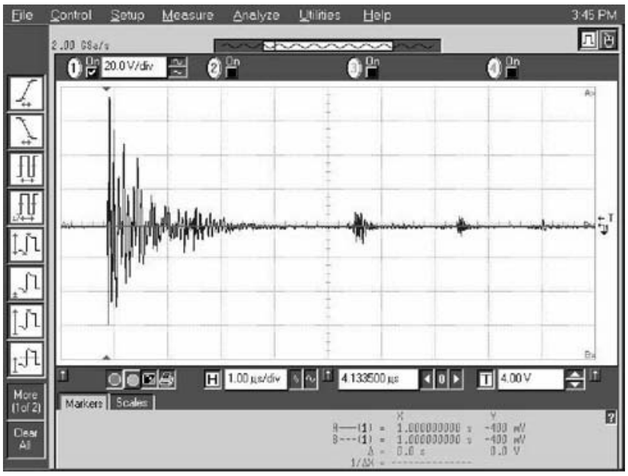


Figure 3. Waveform for 11 kV Output Measurement Performed in Shielded Room (amplitudes are 8 dB amplified)

B. Anechoic Chamber Measurement

In order to be isolated from outer environment, it's more sensitive to perform the tests in an anechoic chamber. The chamber used for the tests have dimensions as 7 x 3 x 3.4 m (L x W x H). Test setup was arranged like in the shielded room. Instead of copper plane base, circuit laid on a polistern material, 1 m above the floor. First the gap of the switch is set to a specific distance; 1 mm for example, then output voltage is raised till a breakdown occurs. Breakdown level is marked and the output waveform is saved with data.

This procedure is repeated for various gap distances and voltage levels. Each test is performed with the antenna 1 m and 2 m away from the circuit.

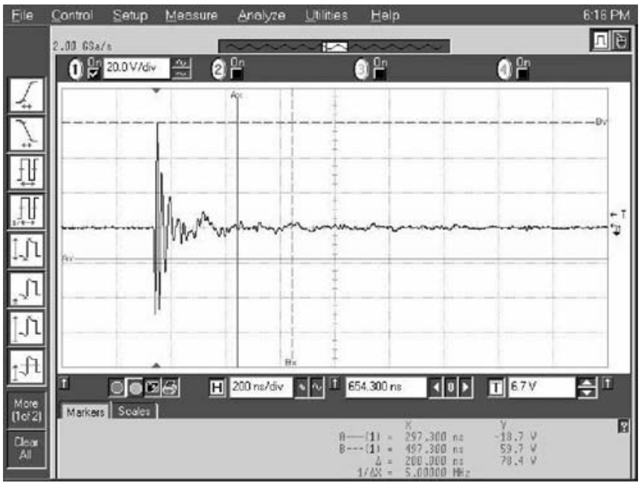


Figure 4. Waveform for 5 kV Measurement in Anechoic Chamber (amplitudes are 8 dB amplified)

III. MEASUREMENT RESULTS

Tests performed in shielded room and anechoic chamber gave a chance to evaluate the effect of different voltage levels. Comparing the results of two environments, we can state the effect of the reflections. For the tests made in anechoic chamber, transient field signals are measured at a distance of 1 m and 2 m. According to the results obtained from the tests, graphs of max E-field amplitudes versus output voltage of hvdc supply is given for both environments at Figure 5 and Figure 6.

It is no surprise that the magnitude of the E-field radiation increases as the output voltage of the supply is raised. Comparing the amplitudes obtained at 1 m and 2 m distance, an inverse proportion is clearly realized. When the waveforms are studied it is seen that the transient components forming the interference have a total duration of about 20-30 ns each. The rise times are not more than a few nanoseconds.

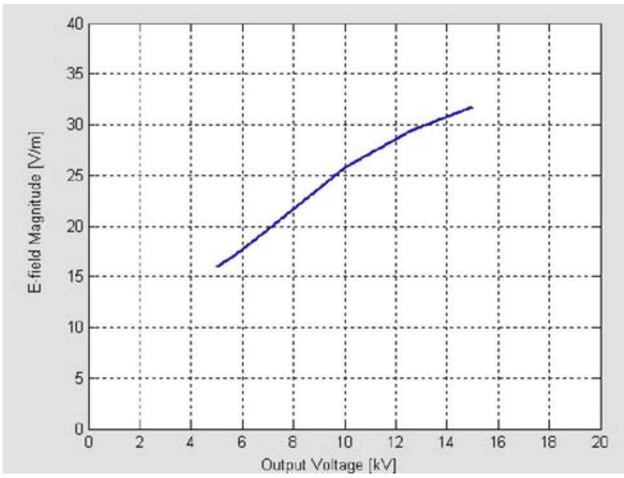


Figure 5. E-Field Magnitudes Obtained in Shielded Room

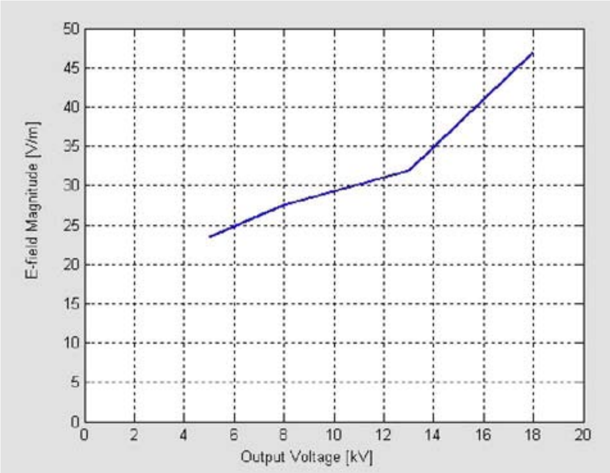


Figure 6. E-Field Magnitudes Obtained in Anechoic Chamber

IV. FREQUENCY DOMAIN RESULTS

The results of the measurements are saved in time domain. To evaluate the transients in frequency domain, FFT of the data are made. Figure 7 gives the field magnitudes at different frequencies. The maximum magnitude of field seems to be effective at 15 MHz. Transients have a wide band spectrum as 100 MHz.

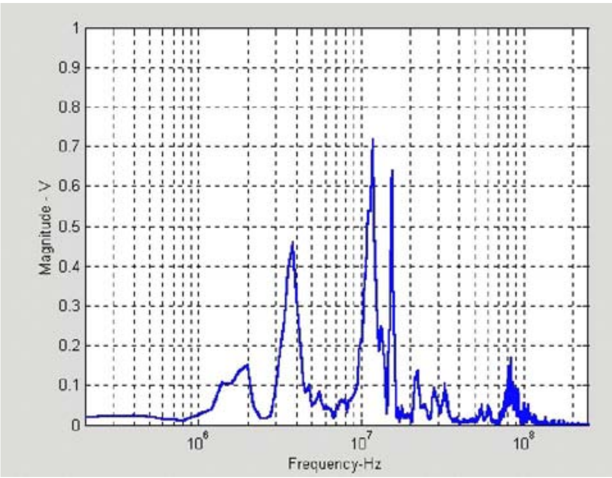


Figure 7. Frequency domain Response of the Transients for 11 kV Output

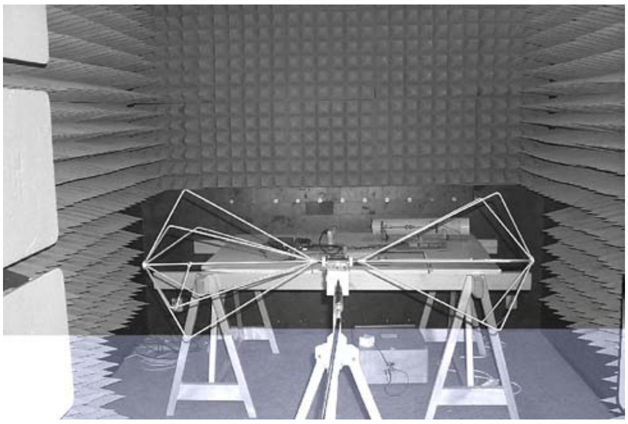
V. CONCLUSIONS

Electromagnetic interference from a high voltage impulse generator is mainly caused by the spherical air gap switch. Interference of the switch increases with the applied voltage (gap space) and decreases with the distance from the source. Radiation has a wide band as 100 MHz, and the peaks are observed at 3-12-15 MHz. For an output voltage of 18 kV, an interference with amplitude of 47 V/m peak is obtained which is enough to effect an electronic circuit.

Tests are performed for spherical switch with air gap and no pressured gas or metallic case. In order to reduce the interference to a satisfactory level, shielding shall be made both to the switch and the vulnerable system.

The measured values of high fields emitted by a spark from a high voltage impulse generator indicate possible immunity problems for equipment which satisfied the EMC requirements.

Picture 1. Measuring System



Picture 2. Setup In Anechoic Chamber

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VII. BIOGRAPHIES

Aysam Akses was born in Iskenderun (TURKEY), in 9 August 1977. He studied Electrical Engineering at Istanbul Technical University (ITU) from 1995 to 1999. After receiving his engineering diploma, he started his MSc. study at Institute of Science and Technology (IST) of ITU at Electrical Engineering Department and received MSc. degree in 2001. His main study and thesis was on High Voltage Generation, Impulse Voltages, EMP, LEMP and General Installation. He is PhD. student at IST of ITU since September 2001. He is also working as a Researcher at National Research Institute of Electronics and Cryptology (TUBITAK-UEKAE) since September 1999 on EMC, High Power, High Voltage and Electrical Installation.

Mehmet Yazici was born in Rize (TURKEY), in 28 June 1972. He attended to Yildiz Technical University (Istanbul) in 1989 and studied Electronics and Communication Engineering until 1993. He started his MSc. study at Gebze Institute of Technology E.E. Department in 1997 and received diploma in 2000. He is a student of PhD. at the same department since 2001. He is a researcher at TUBITAK-UEKAE since March 1997. His main working areas are EMC, Computational Electromagnetics and Power Electronics.

Özcan Kalenderli was born in Istanbul, Turkey, on 1956. He received B.S., M.Sc. and Ph.D. degrees from Istanbul Technical University (I.T.U.) in Electrical and Electronics Faculty in Istanbul, Turkey. He interests the high voltage techniques. He became associate professor in 1998 at I.T.U.

Ersan BARAN was born in Karaman (TURKEY), in 01.06.1974. He studied Electrical Electronics Engineering in Hacettepe University from 1991 to 1997. He started his MSc. study at Sakarya University Electronics Department and received diploma in 2001. He is a PhD. student at Gebze Institute of Technology E.E. Department. He is a researcher at TUBITAK-UEKAE since 1997. His main working subjects are EMC, Instrumentation and Test Automation, Computational Electromagnetics.