Electric Power Systems Research 145 (2017) 83–88

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

One year of x-ray dosimetry in a high voltage laboratory

Welson Bassi*, Márcio Bottaro, Vlamir Viana, Hédio Tatizawa

University of São Paulo (USP), Institute of Energy and Environment (IEE), Av. Prof. Luciano Gualberto, 1289, São Paulo, Brazil

ARTICLE INFO

Article history:
Received 31 August 2016
Received in revised form
20 December 2016
Accepted 21 December 2016

Keywords:
X-ray
Dosimetry
High voltage
Impulse
Laboratory
Radiation

ABSTRACT

Reports of x-rays detection, produced by impulsive voltages in ordinary high voltage laboratories, can be found in the literature. These high voltages are very often to occur in the daily work of the laboratories around the world. This paper presents measurement results of x-ray dosimetry using thermo luminescent detectors (TLD) along 12 months of regular working in the High Voltage Laboratory of Institute of Energy and Environment (IEE) of the University of São Paulo (USP). Experimental tests applying high voltage impulses and placing TLDs in the vicinities of the electrode were performed and dosimetries in these conditions are also presented.

1. Introduction

There are reports in the literature [1–8] that confirm detection of x-rays generated by impulse voltages which can be very frequently found in ordinary high voltage tests in laboratories.

This possible generated X-radiation concerns health matter for workers and often visitors or customers, exposed to several high voltage impulse occurrences during the tests.

Simultaneous measurements of x-rays possibly generated by high voltage lightning impulse voltages are reported in the work [1]. The tests were carried out with the standardized lightning impulse. Fig. 1 shows a typical applied voltage and corresponding current and the observation generated x-rays detected via the scintillation light produced in a barium fluoride (BaF_2) crystal scintillator. The crystal was positioned a few centimeters below the high-voltage rod electrode. According to the authors in about 59% of the 83 applied negative impulse voltages x-rays signals were detected, mainly during the prior period of the voltage collapsing (typical value 1 μs before). Only few cases presented x-rays signals detected before and after flashover across the gap as shown in Fig. 1. The energy deposited in the signals was in the range of some hundreds of keV up to few MeV.

In Ref. [2] it is reported the x-rays observation, detected as bursts, during 14 sparks with 1.5–2.0 m long, in a high voltage laboratory. The discharges generated x-rays are in the range of 30–150 keV and were produced by both positive and negative discharges. Three x-ray instruments containing NaI(Tl) photomultipliers were used for capturing x-rays emission. The instruments were placed around 2 m (distances of 2.2 m and 2.4 m) from the spark gap.

The occurrence of x-rays in lightning impulses produced in laboratory was also detected in both positive and negative polarities in Refs. [3,4]. Experiments were made in Ref. [3] with application of 365 lightning impulses of both polarities (165 positive and 150 negative) using 4 different geometries for the ground electrodes keeping the same gap distance of 58 cm. The detector, NaI(Tl) scintillator, was placed 1 m from the perpendicular of the gap. Both positive and negative impulses produced emission, but a higher percentage of detection as a function of the voltage was found for negative impulses. In Ref. [3] the experiments were made using positive high-voltage pulses of standardized lightning impulses of about 1 MV which were applied to a 1 m gap and a scintillation detector of $LaBr_3$(Ce+) was placed in different distances (0.15–2.1 m) from the electrodes recorded the x-rays emitted during the evolution of the impulse applications. The evolution of discharge process was evaluated with a CCD camera, ns-fast, placed 4 m far from the air gap. The results show that not all the impulse applications generated x-rays and the authors stated that “experimental results clearly demonstrate that the presence of negative streamers is a necessary condition for x-ray generation in metre long positive discharges in the laboratory”. In Ref. [4] the authors have investigated the x-ray emissions from the development of meter long negative discharges using essentially the same setup used as in Ref. [3]. According to the authors the photography

* Corresponding author.
E-mail address: welson@iee.usp.br (W. Bassi).

http://dx.doi.org/10.1016/j.epsr.2016.12.022
0378-7796/

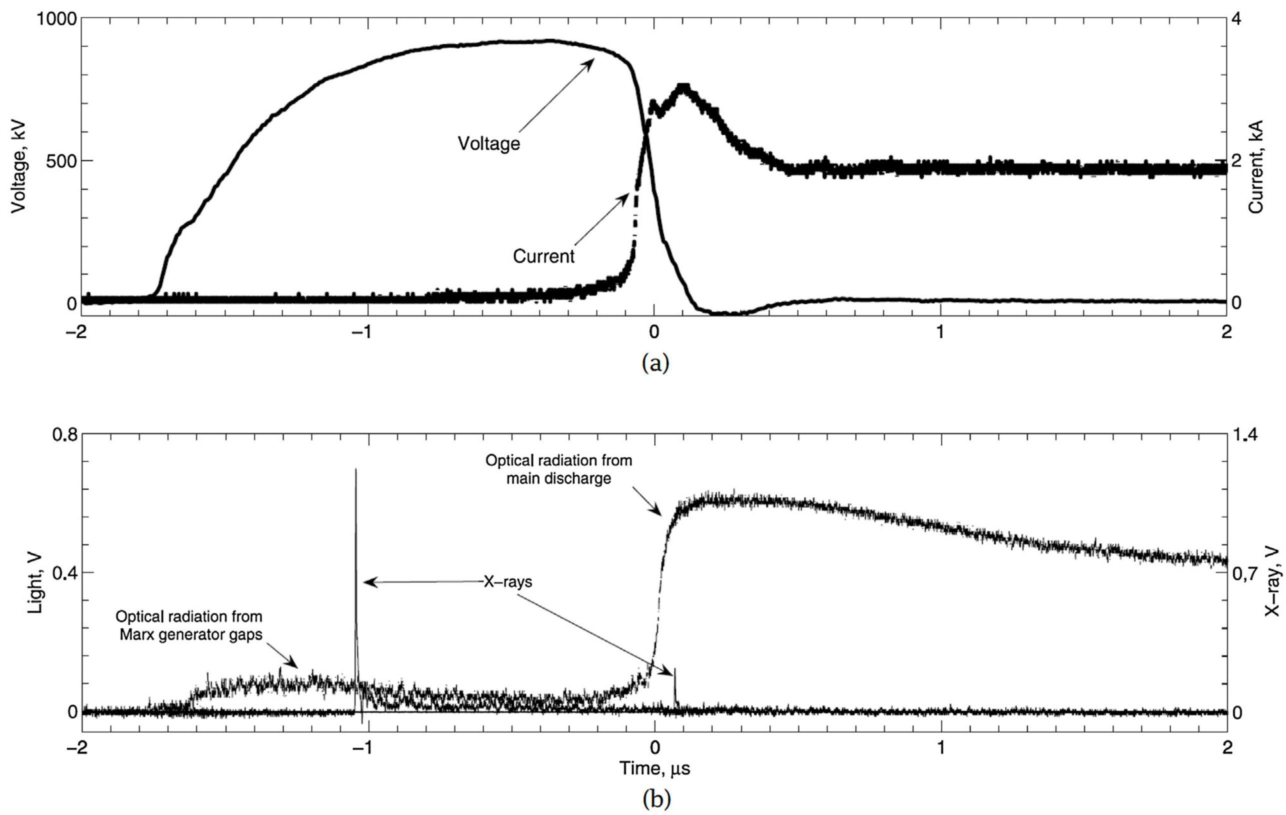

Fig. 1. Function of time recordings (a) applied voltage and current across the 80-cm long air gap (b) optical radiation from the discharge and the x-ray signal [1].

observation with nanosecond fast cameras shows that laboratory discharges with negative polarity have a more complex structure and development mechanism compared to the positive polarities that grow in a more continuous way. The authors correlate the x-ray emission with encounters between positive and negative streamers.

Laboratory experiments using horizontal rod–rod configuration [5] and the detector of NaI(Tl) scintillator placed 1.2 m from the air gap have shown that the faster (low risetime) voltages growth the higher probability of x-ray production, with higher energies. In the same study, using a rod-plane configuration some series of impulses with positive and negative polarities were performed resulting no x-ray detection in the positive impulses.

The detection of x-rays and simultaneous occurrence of microwave RF power in the range of 2.4 GHz is presented in Ref. [6]. The measuring cabinet contained a scintillation detector and a receiver tuned at 2.4 GHz and pass-band of 5.5 MHz. The experiments have shown systematic peaks measured in the RF power signal at the time of the x-rays generation. The discharges producing sparks present peaks of RF radiation before the breakdown of the gap and it were also detected RF peaks in voltage application without provoking breakdown. In the applications where x-rays were detected higher RF power were measured. According to the authors the results indicate that, along the high voltage discharge process, electrons are very fast accelerated letting, in some cases, to produce x-rays. The microwave radiation and the x-rays may derive from the same process.

In Ref. [7] experimental tests were performed using standard lightning voltage impulse of 1.2 μs front time. Various scintillator detectors with different response times recorded bursts of hard radiation in nearly all surges. Also, the authors state that in spite of the symmetry of the gap, negative impulses produced more intense radiation than the positive ones.

In Ref. [8] other experiments were performed applying switching standard impulses over a 35 cm air gap in horizontal and vertical configurations. Three x-rays detectors were used. From series of 15 negative polarity applications the maximum detection rate was the occurrence of 8 detections when using vertical configuration.

The previous articles have indeed confirmed the occurrence of x-rays produced by high voltage impulses in laboratories in a time preceding the occurrence of flashover over the separation gap between the electrodes.

The utilization of lightning standard impulses is a common routine on testing laboratory. Every year, thousands of high voltage impulse applications are expected to happen. One could assume, as a consequence, that some x-ray dose might be absorbed by the occupationally exposed laboratory personnel and/or the visitors, customers, students and other non-occupationally exposed people that take part in the activities.

The reference doses for different exposition conditions are presented in the ICRP Publication 103 [9]. The annual equivalent dose limit of 1 mSv for exposures of the public from all practices (considering prolonged and transitory) are considered applicable for the laboratory staff and its users.

None of the previous studies have performed dosimetry evaluation in both personal and in the internal area of the laboratory (environment).

In this work, radiation dosimetry was carried out in order to assess the associated dose values to x-rays during the regular operation of a general purpose high voltage laboratory where dozens of scheduled tests were performed over one year.

Additionally to the radiation dose measurements during regular routine in the laboratory, specially prepared tests were performed and particular dose measurements were taken in some experimental arrangements.