Defects Detection in Electrical Insulators and Breaker for High Voltage by Low Cost Computed Radiography Systems

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Abstract
Nondestructive inspection of electrical insulators subjected to the high electrical stress and environmental damage is fundamental for reliable operation of a transmission lines and substations. At the present work, the glass and composite insulators used for several years in a transmission line and an oil controlled hydraulical breaker in substation were investigated by low cost computed radiography systems consisted of a portable X-ray of 270 kVp and 1.5 Ci of activity Ir-192 gamma-ray sources . For a better evaluation of glass and composite insulators, good insulators were also tested. As a result, the cracks and operation defects could be readily detected in the insulators and breaker, respectively.
Keywords: Electrical insulators, transmission line, high voltage, defects, cracks, computed radiography

1. Introduction

When an electrical insulator or breaker is in operation at the high voltage transmission line systems, for example: 138 kV, 230 kV and 500 kV or higher voltages, those devices are subjected to a strong electrical stress and also damage by the environmental conditions [1]. It is well known that the presence of voids and inclusions introduced in the manufacturing processes, or generation and propagation of cracks inside the electrical insulators, when those devices are in operation under high voltage stress, a partial discharge begins as localised dielectric breakdown. Furthermore, partial discharge can also occur along the boundary between different insulating materials. Once begun, partial discharge causes progressive deterioration of insulating materials, ultimately leading to electrical breakdown and, eventually, explosion with stop of energy transportation [1]. Furthermore, breakers for high voltage applications at substations are complex electromechanical system and usually, they are oil controlled operation system. For safety reason, in the normal operation, the pistons should move smoothly along the cylinders filled with special oil of high dielectric strength. However, in a long operation under high voltage electrical stress, a corrosion process can take place inside of the cylinder and, eventually corroded materials deposit on internal wall making pistons moviment difficult or stop. Therefore, previous detection of these kinds of defects in electrical insulators and breakers by non-destrutive tensting method is of the fundamental importance to minimize interruption of energy and accidents.
At the present work, in order to evaluate the potentiality of high sensivity of reusable storage phosphor screens, known as IP - imaging plate, that has some advantages such as they do not require chemicals for film processing, and it is interesting from radiological protection point of view, computed radiography of low cost were used to obtain the good digital radiographies using compact X-ray and gamma-ray sources and

low cost systems for imaging plate reader [2,3]. These systems were used to evaluate the high voltage glass and composite insulators from transmission lines and also an oil controlled hydraulical breaker of substation, all of them employed for several years. The employed X-ray and gamma-ray sources were a portable X-ray and 1.5 Ci of activity Ir-192 gamma-ray. In order enhance some details on as obtained radiographic imagens for comparison, digital imaging processing was also performed employing mathematical filters.

2. Methodology

At the present work, in order to evaluate the the resolution of computed radiography for potential application in detection of defect in the high voltage electrical insulators and breaker, first, one good glass insulator and another with glass part broken were evaluated using computed radiography system consisted of gamma-ray of Ir-192 with 1,5 Ci and focus size of 3 mm coupled with imaging plate reader originally developed for dental application, Denoptix scanner made by Gendex. From operation point of view, a good and clean glass insulator of 10 inch in diameter resist up to 80 kV, while a broken one, no more than 10 kV.
In order to evaluate the structure integrity of composite insulators of 2400 mm long employed for than 10 years in transmission line of 230 kV under high voltage stress and environmental conditions: pollutions, hummidity, ultraviolet radiation and so on, and also hydraulically controled breaker employed for long time at a substation were inspected by the computed radiography system consisted of compact X-ray source of 270 kVp, model XRS-3 from Golden Engineering coupled with a similar imaging plate reader, however, model Cyclone from Perkin-Elmer. Two types of imaging plate were employed: super resolution imaging plate (blue type) and super sensitive imaging plates. Digital imaging process were conducted employing IPT – imaging process toolbox and LOG filters of Matlab software.

3. Results and Discussion

Figure 1 shows photos of parts of glass insulator of good glass insulator and broken one. A glass insulator works as a electrical capacitor so as tempered glass is between two metallic parts made of steel, which are cemented by a special cement.

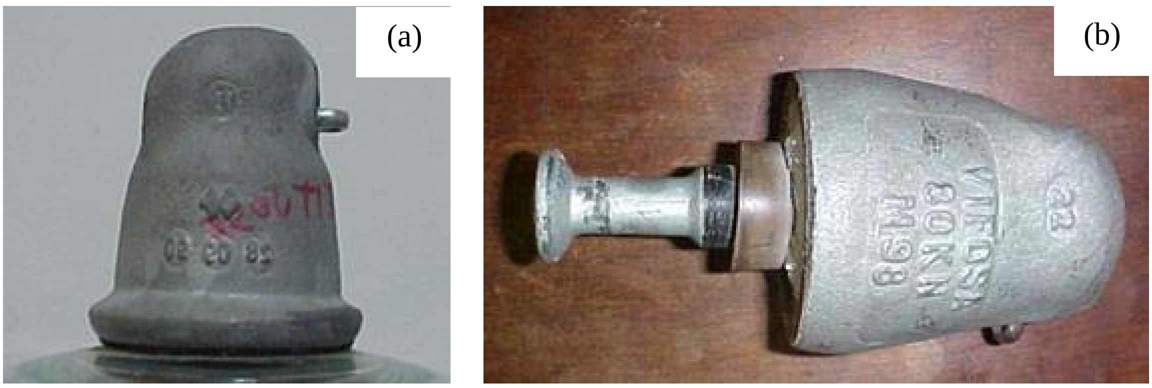
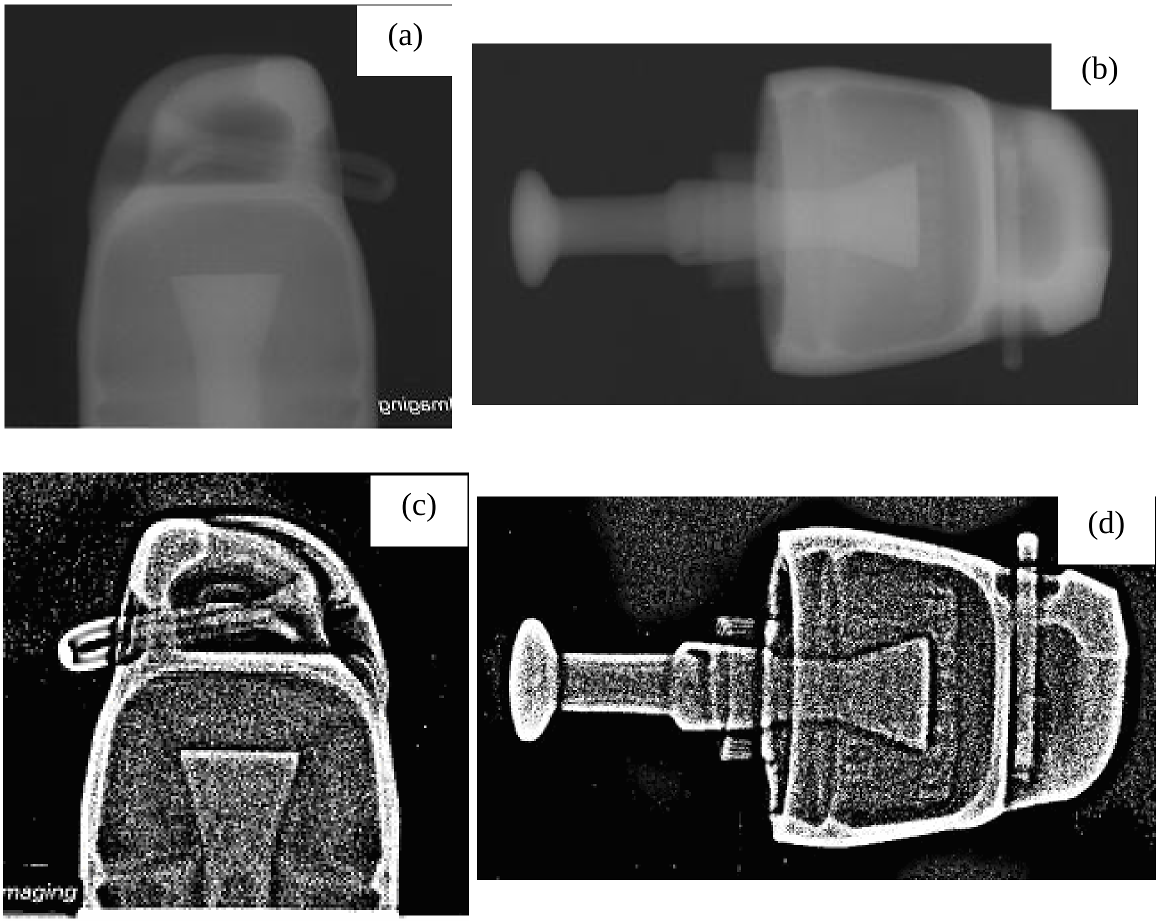


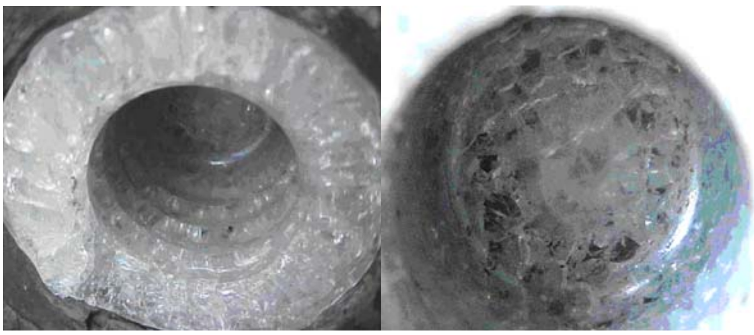
Figure 1. Photos of glass insulator employed in a high voltage transmission line: (a) upper part of a glass insulator of 10 inch in diameter and 80 kN; and (b) glass insulator with glass part broken.

Figure 2 shows as obtained digital radiography and processed radiographies by Matlab using IPT and LOG filter. In principle, even though the quality of radiography are considered good and a texture can be observed only in figure 2(b), which it was attributed to glass cracks texture on digital radiography, however, it can be easily observed after LOG filter application as shown in figure 2(d).



Figures 2(a) and 2(b) are as-obtained digital radiographies. 2(c) and 2(d) show processed digital radiographies of radiographies shown on 2(a) and 2(b) by LOG filter.

In order to assign that texture observed on digital radiography using Ir-192 gamm-ray source with 1,5 Ci activity coupled with IP reader Denoptix, one of metallic part cemented to glass part was carefully extratect from the broken glass insulator. Figure 3 shows clearly that tempered glass broke also in the interior region.



Figures 3 shows the interior part of tempered glass in two magnifications after the the extractetion of one of metallic part. It is clearly observed that whole glass part is cracked.

Figure 4 shows a photo of composite insulator evaluated by the computed radiography.

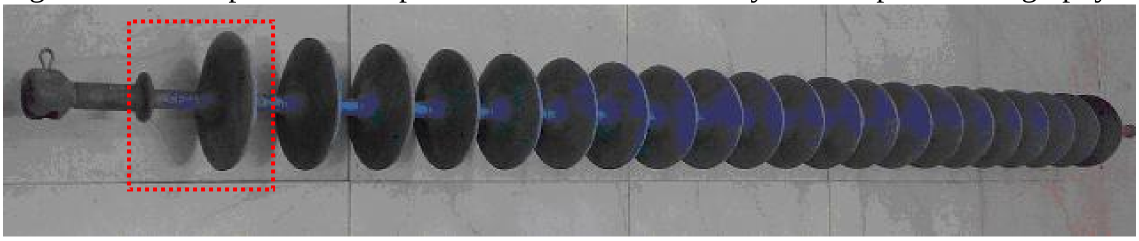


Figure 4 shows a photo of composite insulator employed in high voltage transmission line of 230 kV showing part that was imaged by the computed radiography.

Figure 5 shows as-obtained digital radiography of good composite insulator and one with cracks on polymeric part. Visualization of those cracks by the naked eyes are most of time difficult because the surface usually is coated with dust. Therefore, computed radiography can easily detect such cracks.

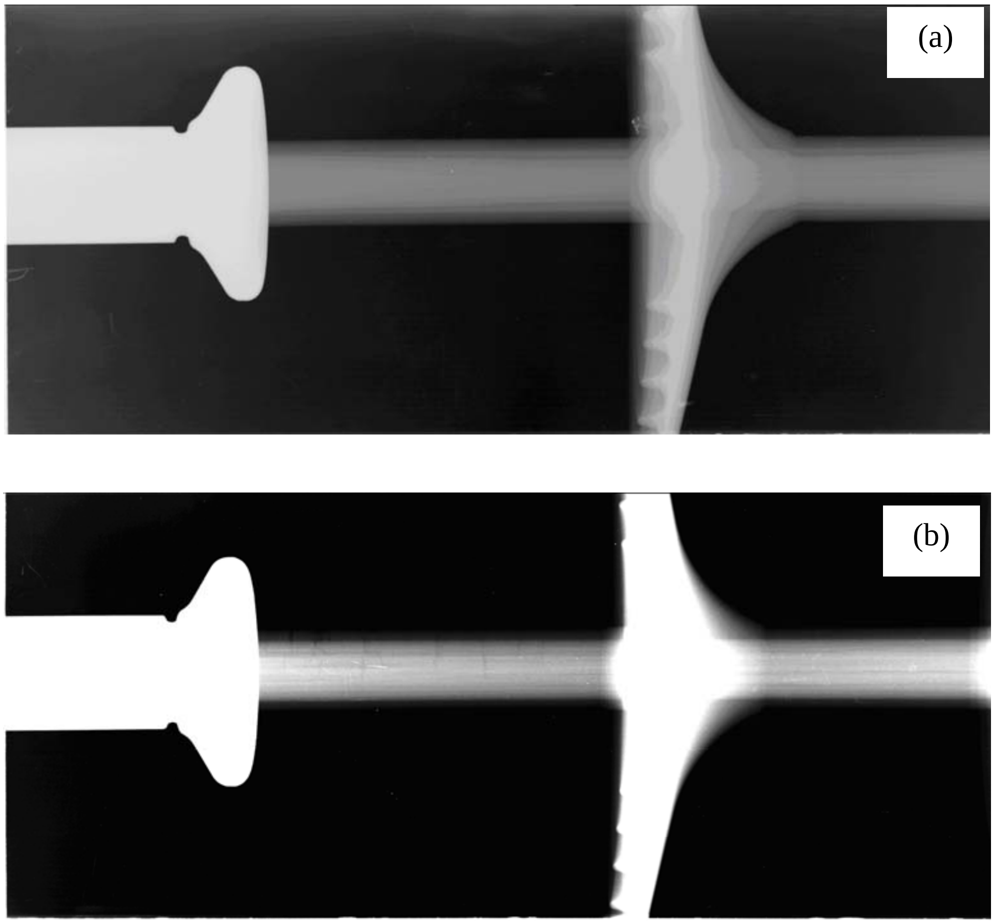


Figure 5 shows as-obtained digital radiography of composite insulator classified as good (a) and with cracks on external polymeric materials

In order to enhance those cracks that are visible on as-obtained digital radiography, figure 6 shows two digital radiographies processed by embossy and LOG – Laplacian and Gaussina filters. The cracks appear perpendicular to composite axis. When the LOG filter is applied, scratches on the imaging plate also evidenced, but beyond cracks, the fiber texture is also enhanced.

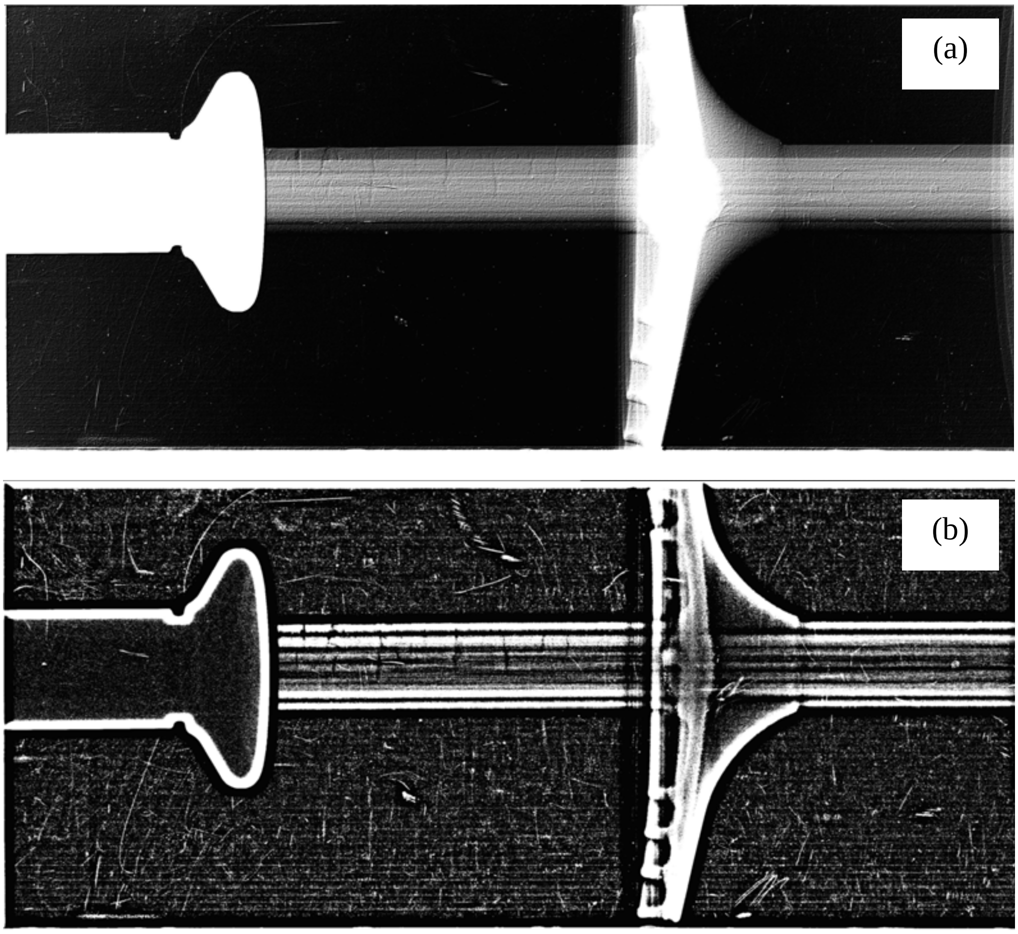


Figure 6 (a) Digital radiography processed by emboss filter, and (b) processed by LOG filter.

Another interesting result was the possibility to observe the composite material in the interior of metallic end, as shown in figure 7. Radiographic image was obtained reducing the distance between IP and the X-ray source to about 250 mm.

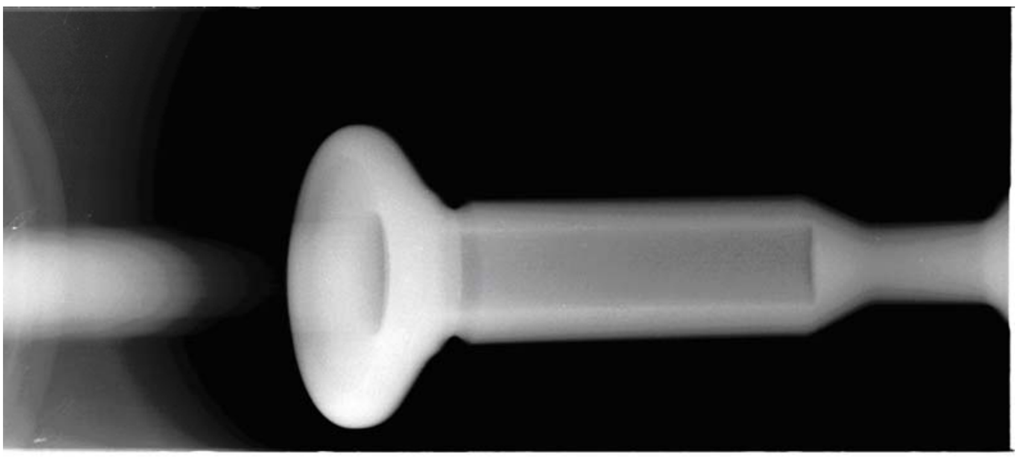


Figure 7 –Composite part in the interior of steel glove.

Figure 8 shows a photo a breaker at substation and digital radiography with emboss filter applied. In normal operation, the both valves should be at the same level, however, the radiography revealed easily that some kind of material deposited on inner wall of cylinder making difficult one of valve move along it.

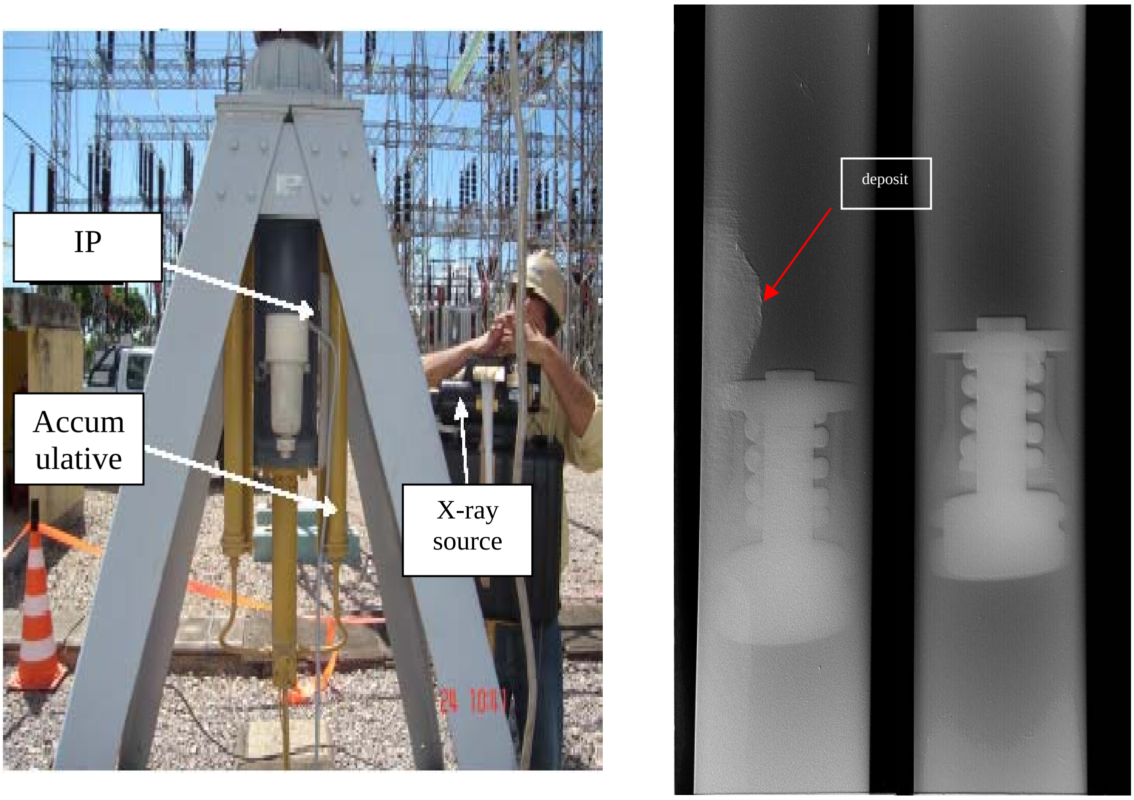


Figure 9 –Photo of break system at a substation and digital radiography with emboss filter showing deposition of materials on inner wall of cylinder making difficult the moviment of one of valves.

4. Conclusions

Based on results presented in this work, the low cost computed radiography systems showed good potentiality to detect, relatively easily, several kinds of defects such as cracks in insulators of high voltage transmission lines and material deposition on internal wall of breaker cylinder making difficult the valve moviment.

Acknowledgements

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