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Electrostatic Shielding of Faraday's Ring Made of Stainless Steel 304 in the Glass Insulators

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Abstract

High voltage glass insulators are equipment used in power transmission or distribution networks. They consist of a metal bell, a metal pin and a glass or porcelain disk. The joint action of atmospheric pollution, humidity and an intense electric field on the surface of these insulators accelerates the process of corrosion in the metal pin parts, resulting in catastrophic failures in the entire electrical system. In this sense, this case report presents an electrostatic protection device that, aiming to shield the surface of the pins against the pernicious electrical influences, was designed as a screwable Faraday cage made of stainless steel 304 and was denominated "Faraday's ring". To validate the efficacy of the device, electrical field simulations were carried out in 2D models of chains of insulators, which were developed using software that is based on the Finite Element Method, and experimental tests were also carried out with the aid of a Tesla Coil to supply electric discharges on the metallic surface of the device. The simulations and experimental results showed that the device was able to cancel out the intense electric field of ~ 3

$\times 10^3$ kV/m in the outer surface and avoid the onset of corrosion within.

Keywords: Electrostatic shielding, Faraday's ring, Glass insulator, Metal pin, Corrosion.

Introduction

Glass cap-on-pin insulators or simply glass insulators are electric equipment widely used in the overhead lines of the electric system. They consist of a dielectric disk coupled between a metal carbon steel cap and pin [1], as shown in Figure 1(a). The pin has a zinc ring at the base to avoid corrosion. However, these pins can suffer severe corrosions under a high electric field, usually corresponding to voltage transmission lines greater than 69 kV, and atmospheric pollutions associated with high humidity, as shown in Figure 1(b). These combined factors are majorly responsible for several catastrophic failures in the overhead lines [2]. The corrosion occurs immediately after deposition of aerosol particles on the dielectric shell, thus an electric circuit is formed between the cap and the pin of the glass insulator,

Figure 1: a) Characteristics of the glass insulator and b) severe corrosion in the pin sleeve (white arrow) caused by environmental pollution

initiating the flashovers in the zinc ring. This phenomenon consists of partial electric discharges that are intensified in tropical or coastal regions, because of high rainfall or salinity in these zones, respectively. Several solutions have been proposed to mitigate these factors [3,4], e.g. replacing aged glass insulators based on corrosion of zinc sleeve [3] or changing the insulator profile as a response to different pollutants from environment [4]. Unfortunately, this corrosion remains a cause of serious concern. In this sense, we proposed a new approach, that was able to maintain the same profile of the glass insulator or that kept the zinc ring unchanged, while avoiding the occurrence of flashovers on the pin surface. The solution consists of a device called a Faraday's ring that is coupled on the pin of the glass insulator (see Figure 2) [5]. Table 1 shows the chemical composition of the stainless steel 304 alloy used to manufacture the device, which is a chromium-nickel alloy with low carbon content. Besides, it is screwable as well as adjustable, thus permitting a Faraday cage-like configuration.

Case study: Simulation

The simulations were performed via the finite elements method (FEM) using the COMSOL MULTIPHYSICS® software package in order to obtain electric field distributions surrounding a pre-defined set of five glass insulators with/without Faraday's ring coupled in the pin sleeve under

high electric voltage of 69 kV, as shown in Figure 3. Table 2 presents the parameters used in this simulation.

Figure 4 shows plotted data from electric field intensity at a shorter distance of 45 mm on the pin surface with/without electrostatic shielding protection, where the result displays clearly that the Faraday's ring acts like a Faraday cage. The pin surface without the protective device shows an intensity of approximately 26 kV/m, while the electric field was null in the protected pin surface configuration. Moreover, the electric field distributions surrounding the assemblies of glass insulators under 69 kV remained unchanged, i.e., the inclusion of the Faraday's ring did not change the electric field distribution around overhead transmission line.

Case study: Experimental tests

The experimental tests were performed with a Tesla coil in order to obtain the flashovers in the pin sleeve of the glass insulators with/without Faraday's ring. The electric field generated was greater than $\sim 3 \times 10^3$ kV/m, which was necessary to break down the air dielectric strength. The Faraday's ring avoids propagation of flashover in the base of the pin surface as seen in Figure 5(a) and 5(b). Thus, a cage Faradays is performed whenever two glass insulators are assembled with the device, as shown in Figure 5(c). Therefore, the onset of corrosion in this region of glass insulator is avoided as well.

Figure 2: Faraday's ring consists of three parts: **1)** a rubber socket attached into **2)** and **3)** two screwable metallic rings and their coupling mechanism in the glass insulator. The dimensions of the parts in mm

Table 1: Chemical composition (%) of stainless steel 304

C*	Mn*	Si*	P*	S*	Cr	Ni	N ₂ *
0.08	2.00	1.00	0.0045	0.03	18.00 – 20.00	8.00 – 10.50	0.10

* Maximum percentage

Table 2: Physical parameters used in the FEM simulation

Material	Relative Permittivity	Electrical Conductivity (S/m)
Air	1.00	0.00
Cement	1.00	0.00
Glass	4.20	1.00×10^{-14}
Steel	1.00	4.03×10^6
Iron	1.00	1.12×10^7
Aluminum	1.00	3.77×10^7

Figure 3: Discretization steps from **a)** real configuration, **b)** 2D model and **c)** FEM mesh

Figure 4: FEM for electric field intensity and their distribution around assemblies: data from electric field intensity on the pin surface **1)** with/2) without device and the electric field distribution plots (Inset). Arc length in mm

Figure 5: Flashover discharges **a)** in the surface of the pin head and **b)** in the electrostatic shield. The Faraday's ring mounted between two glass insulators performs **c)** a Faraday cage

Conclusions

Faraday's ring design is a viable solution for correcting the corrosion problem in the glass insulators, as it does not require changing their profile or increasing the zinc sleeve of the pin. Even though the device may suffer damage caused by flashovers under

severe environmental pollution, the integrity of the insulator will be maintained because Faraday's ring continues to work like Faraday cage. Moreover, this device can be manufactured by metalized plastics technology aiming to decrease the weight of the piece and make it cheaper.

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