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Review

Porcelain insulators in electrostatic precipitator

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A B S T R A C T

Electrostatic precipitators (ESPs) are commonly the most used filtration technology at industrial environments considering that ESPs allow to have a high dedusting efficiency. ESP insulators are key components in a precipitator inasmuch as if they do not work properly, the efficiency decreases quickly, and even having an inadequate insulation can end up in a serious accident. Therefore, there are several recommendations given about the adequate material for each insulator type and also about how to maintain an ESP insulator in good working conditions.

1. Introduction

Electrostatic precipitators are large industrial emission control units which are designed to trap and remove dust from exhausted gases. They are the most used popular devices to control air pollution in many industrial applications such as cement kilns, coal fired boilers, incinerators, steel plants and others [1–4]. Electrostatic precipitators involve several complicated physical processes such as charging of particles, transporting them to the collecting surfaces and removing them [5].

When high voltage direct current (HVDC) is applied to the discharge electrode, a corona discharge takes place. Ions and electrons are produced at the corona point, and ionic current flows through the space. The ion polarity is either positive or negative. These ions attach to suspended solid particles. These charged particles are moved towards the collecting electrode by a Coulomb force, and are collected on that electrode. When the thickness of the layer formed by collected solid particles reaches a predetermined level, the collecting electrode is rapped mechanically using a hammer, and the layer falls down into a hopper located below. These particles are then carried away to outside the ESP [6,7].

The electrostatic precipitation process occurs within an enclosed chamber, a high-voltage transformer (to step up the line voltage) and a rectifier (to convert AC voltage to DC) provide the power input. The precipitation chamber has a shell made of metal, this shell allows the collecting electrodes (also known as plates) to be hung up from several frames. Suspended between collection plates are located the discharge electrodes (also known as corona electrodes), which are insulated from ground and negatively charged with voltages ranging from 20 kV to 120 kV [8]. The large difference in voltage between the negatively charged discharge electrode and positively charged collection electrode creates the electric field that drives the negatively charged ions and particles toward the collection electrode. The particles may travel some distance through the ESP before they are collected. Some particles lose their charge rapidly after being collected and are lost through re-entrainment in the gas stream.

There are several features of the electrostatic precipitator process, which produces an ideal vehicle for the removal of particulates. The performance can be close to 99.5% [5] and the maintenance requirements in order to keep this high performance is lower compare with other industrial facilities. If the maintenance is carried out properly, ESP life expectancy will be over 20 years [8].

All electrostatic precipitators, regardless of their particular designs, contain the following essential components: discharge electrodes, collection electrodes, electrical supply system, electrical insulators, rappers, hoppers and shell.

Electrical insulators are fundamental elements for precipitators because they are capable of providing several functions such as insulation, stiffness and supporting mechanical and electrical

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forces and torques. A part from those tasks the main goal of the ESP insulators consist of insulating electrically the rest of the ESP components. If the ESP insulators did not work properly or they were damaged, the electrostatic precipitator efficiency would decrease strongly. In addition, a damaged insulator could cause serious damages to other components. which means an unexpected stoppage in order to replace the elements. Definitely, ESP insulators are main elements in precipitators. So, a really important goal must be the maintenance of the insulators.

In order to differentiate between ESP insulators and insulators form others electrical devices like transformers [9] or transmission lines [10], the last ones will be named as normal insulators from now on. A comparison between normal and ESP insulators show that there are a great deal of differences between them. Not only should ESP insulator have bigger creep distance (the shortest path between two conductive parts measured along the surface of the insulation) and dust-free shape, but also there should be differences in working conditions and materials they are made of.

Regarding working conditions, ESP insulators have to support at higher temperatures than normal ones. The temperature range that ESP insulators have to support varies from 100 °C up to 800 °C in extremely situations [8]. However, normal insulators reach much lower temperatures. Besides, ESP insulators have to support raw gas, which has a large amounts of dust, whereas common insulators support only the atmosphere pollution.

As regards materials, ESP insulators are mainly made of porcelain (in some cases insulators can also be made of composite [11]) due to its good thermal properties. Normal insulators used to be made of porcelain, but nowadays most of them are made of glass and composite is playing an increasingly important role [12].

There are many documents in order to discuss insulators from line transmission and transformers [12,10,9,13]. Nevertheless, regarding ESP insulator there are not many documents and they are highly spread. The purpose of this review is to unify the spread information about ESP porcelain insulators in so important fields such as main materials, principle failures, proper maintenance and likely reparations. The content of this article is distributed as followings paragraphs show.

Section 2 is about the main working conditions that can arise in an electrostatic precipitator. As it is mentioned below, there are several parameters to take into account when an ESP is working. Among these values, we can focus in working temperature, flue gas traces and resistivity. This section discusses what happens when these parameters varies.

Section 3 deals with the selection of the key type of porcelain and also several guidelines about glazing are presented. As for the type of porcelain, there is a comparison between the porcelain that was used many years ago and the current advanced alumina porcelain. A part from this comparison, this report presents a suggestion as regards the proper porcelain for each type of insulator.

Section 4 states the main problems that can arise in an ESP insulator, these negative aspects are typically well-known like thermal breakdown and insulation ageing. Besides, it is suggested some measurements so as to avoid these failures.

Section 5 talks about maintenance. As we will see below, maintenance is one of the most important aspects as long as insulators are concerned. This document shows how to implement a best code of practises such as cleaning an insulator by using alcohol. In addition, several techniques are explained to prevent dust from insulators as well as an important device in order to help to these methods.

Finally, Section 6 provides some information about when an insulator can be repaired. This information can be quite important because the current tendency is to replace the insulator without trying to repair it before the replacing.

2. Working conditions

Generally, electrostatic precipitators are used to work under a wide variety of conditions. For example, an ESP that belongs to a cement plant has not the same working conditions as an ESP from a sinter plant, therefore, an average idea will be presented from now on [14,15].

Gas composition, temperature and resistivity are the main parameters that define the working conditions of an electrostatic precipitator.

Frequently, ESPs work with a minimum temperature always above the dew-point (the exact acid dew-point is variable [16]). Besides, the temperature is limited by construction materials. If the casing and internal components are made of steel the maximum temperature should be up to 400 °C [8]. For higher temperatures, other materials like stainless steel and others alloys must be used. For example, a typical temperature from steel industry is approximately 170 °C.

Another limitation is the electrical operation and hence the ESP performance. The higher temperature, the lower breakdown voltage.

Features so important like resistivity varies with the gas composition. Depending on the industrial process, flue gas will be formed by several gases such as nitrogen, etc. Resistivity is an intrinsic property of the gas composition. The resistivity of the particulates has a wide range, but this range can be limited between 10^8 and 10^{12} Ωcm. Where, resistivities close to 10^8 are considered low resistivities. Nevertheless, resistivities near 10^{12} belong to the high resistivity group of flue gas [8]. However, characteristics like viscosity and density are related to not only to the gas composition, but also to the temperature. The higher the temperature, the higher viscosity.

All these characteristics of the gas give an idea about the type of dust that there will be in the ESP (e.g., sticky dust). The kind of dust is really important for insulators, for example, a really sticky gas can reduce the insulator performance more than a non-sticky one.

3. Typical features of ESP insulator

Many years ago, ESP insulators had a good properties for those times. Nowadays, those characteristics would not be enough and they would be considered as poor high tension insulators. They could not provide so high properties as the modern ceramic materials such as alumina porcelain, alumina, silicon, nitride, silica, etc.

Generally the main requirements for any support insulator is that the material must have enough strength to support the weight of the discharge electrode system (each weight is close to 11.4 Kg); It must be sufficient strong to suffer voltages up to approximately 120 kV and high temperatures.

This section provides a comparison among the main porcelain materials so as to illustrate about what type of porcelain is better for electrical insulators at ESPs. Also, it is suggested what type of porcelain is better for each type of insulator (depending on the location of the insulator). Finally, the most spread coating for insulators (called glazing) and its suitable working conditions are shown with the purpose of clarifying when it is useful.

3.1. Materials for ESP insulators

At the beginning, common standard electrical porcelain insulators were used as insulators in electrostatic precipitators. Insulators were manufactured from vitreous materials (e.g., clay-feldespar quartz) which were supposed to have enough dielectric and mechanical strength, high thermal shock resistance and so on (see Table 1) [17].