Engineering Failure Analysis 65 (2016) 48–56

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Heating phenomenon in unclean composite insulators

Cong Wang [a,*], Tianfu Li [a], Youping Tu [a], Zhikang Yuan [a], Ruihai Li [b], Fuzeng Zhang [b], Bo Gong [b]

[a] Key Laboratory of High Voltage & EMC, North China Electric Power University, Beijing 102206, China
[b] Electric Power Research Institute of China Southern Power Grid Co., Ltd., Guangzhou 510080, China

ARTICLE INFO

Article history:
Received 24 September 2015
Received in revised form 7 March 2016
Accepted 14 March 2016
Available online 21 March 2016

Keywords:
Composite insulator
Temperature gradient
Relative humidity
Polarization loss

ABSTRACT

Abnormal heating phenomenon may be the precursor of fracture on composite insulator in the transmission line. In this paper, in order to study abnormal heating phenomenon of composite insulators during regular inspection, two operating composite insulators which had been in service for six years in 500 kV transmission line, and a new composite insulator of the same type, were inspected by infrared imaging tests. To understand the characteristic of temperature gradients varying with pollution level and relative humidity (RH), infrared imaging and leakage current of the samples with different amount of pollution placed in the climatic chamber were monitored. The results show that uneven heating along the housing occurs on the high voltage end. With the increase of the pollution level, the phenomenon of temperature rise becomes severer. What's more, RH was found to play an important role with the heating phenomenon. By analyzing the results of temperature rise under different RH with various levels of pollution, the abnormal heating on the polluted composite insulators was found to be caused by polarization loss of the water absorbed by the interface of the housing and resistive leakage current induced by pollution on the high voltage end.

Contents

* Corresponding author.

http://dx.doi.org/10.1016/j.engfailanal.2016.03.016
1350-6307/

1. Introduction

Silicone rubber of composite insulators gets worse when contamination on the composite insulator accumulates due to atmospheric pollution nowadays [1]. In the meantime, phenomenon of abnormal-heating occurs among composite insulators in transmission lines. In 2010, one composite insulator servicing in Luobai Line performed temperature abnormality and it fractured about a month later. It is probable that temperature abnormality led to the fracture accident of composite insulator due to the change of material insulating or mechanical properties [2–4]. Accordingly, in 2012, the statistics data in China Southern Grid indicates that 2.5% composite insulators got various degrees of temperature abnormality in four transmission lines during regular inspection. The results also show that abnormal-heating phenomenon of composite insulators not only occurs in heavily polluted areas but also in lightly polluted and highly moist areas. According to [5], an extrapolation can be carried through for a real case. The estimated temperature inside the insulator was 207.6 °C when a 1.4 °C. temperature rise was observed on the surface of a polymeric insulator. According to [6–8], three main heating mechanisms, i.e., heating induced by internal partial discharge caused by conductive defect, heating induced by dielectric loss caused by the water immerged in the housing, and heating induced by resistance loss caused by serious aging of the housing and pollution on the surface, were pointed out Overall, it is of great value to investigate the effect of temperature abnormality on composite insulators for safety insulation.

In recent years, infrared imaging technology is widely used for composite insulators' operating status and on-line monitoring [9–11]. Based on infrared imaging technology, study on temperature abnormality of polluted porcelain insulators was carried out around the world. To calculate the temperature along the string or surface of porcelain insulators, equivalent circuit was simplified and numerical simulation, thermodynamic equilibrium equations, and Maxwell equation were put forward. Then the study found that the highest temperature difference arose at the steel feet and the surface temperature was higher than that of steel tap [12–15]. However, nowadays, there is less study about the effect of pollution on abnormal heating of composite insulators. Furthermore, the temperature gradient of aged and new composite insulators with or without corona rings were compared in [5]. At present, the study of heating of composite insulators is based on methods of porcelain insulators. Thus, personal material characteristic and pollution of composite insulators were neglected during the heating process.

In this paper, in order to explore the mechanism of heating, the different conditions of heating phenomenon have been studied. Meanwhile, the temperature rise caused by pollution was analyzed with characteristic of silicon rubber material. The study results can be a reference to regular inspection of composite insulators in transmission lines.

2. Experiment

2.1. Samples

Three 500 kV composite insulators were selected for the infrared imaging tests. Among these samples, insulator #1 was from the transmission line near the sea with gradient temperature of 5 °C while insulator #2 was from the line on the land with gradient temperature of 6.3 °C. In this paper, gradient temperature means the temperature difference between the high voltage or the low voltage end and the middle section. In parallel, a new reference insulator #3 was selected, too.

In the experiment, all tested samples, the fitting end and units with one bigger shed, two smaller sheds and housing around the high voltage end were made into a short insulator rod with creeping distance of about 1000 mm. The insulator rod was marked for six units shown in Fig.1 in order to record the results of the infrared imaging tests.

2.2. Experiment setup

In the tests, samples were placed in the artificial chamber whose temperature ranges from 5 °C to 40 °C and RH ranges from 20% to 99.9%.

The AC testing transformer was selected for power supply whose maximum output is 100 kV, protective resistance is 10 kΩ and ratio is 1000:1 of capacitive voltage divider.

With imaging resolution of 640 × 480, temperature range – between 20 °C and 120 °C – and measuring accuracy of ±2%, infrared imaging was carried out by FLIR P640.

On the other hand, leakage current (LC) was obtained through the resistance and an oscilloscope. The schematic diagram was shown in Fig.2.

Where T is the transformer, $R_1$is the protective resistance, F is the capacitive voltage divider, R_2 is the measuring resistance, B is the bushing insulator, C is the artificial climate chamber, TS is the tested sample, and DAQ is the data acquisition system.

2.3. Experiment scheme

Before the experiment, composite insulator rods were contaminated artificially by slurry. According to Chinese standard GB/T26218.1-2010 [19], pollution are classified into five levels a, b, c, d, and e. In the tests, four pollution levels, a, b, c, and d, were chosen for research of temperature abnormality. And the kaolin and salt that is contained in the slurry are in a certain proportion of 6:1 which was shown in Table 1.