Engineering Failure Analysis 92 (2018) 240–267

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Corrosive Sulphur effect in power and distribution transformers failures and treatments

Ricardo Manuel Arias Velásquez*, Jennifer Vanessa Mejía Lara

Pontificia Universidad Católica del Perú (PUCP), Doctoral Engineering Program, Peru

ARTICLE INFO

Keywords:
Corrosive
Data mining
Neural Networks
Sulphur
Transformer

ABSTRACT

In the last years, many power and distribution transformers have a failure mode caused by corrosive Sulphur, partial discharges, explosion or gas generation with Kraft and oil degradation. The degradation process has been unexpected, and the degradation has been determinate by IEC Standards with the traditional analysis, however there are not an earlier recognition than traditional methods, of failure for the transformer diagnosis, with a recommendation for the corrective actions and a methodology to determine the effect before the failure happens. There are some papers for the asset aging, in this research, it is possible to determinate a real correlation and caused failure analysis by data mining, dissolved gas analysis (DGA), physical, chemistry and electrical test with the qualitative and quantitative analysis of the corrosive Sulphur in the transformers.

This research has been developed and it has considered a failure mode caused analysis by corrosive Sulphur phenomenon, the problem was solved on 61 power and distribution transformers, and the novel contribution is a recommendation detection, corrective maintenance, different procedures with advantages and disadvantages the reparation and expected remaining life in the transformers, it will prevent an engineering failure on power and distribution transformers, for high and medium voltage.

1. Introduction

In the last years, a significant volume of researches has been undertaken in order to understand the recent failures in oil insulated in power transformers, due to deposition of copper sulphide on the conductors and in the insulation paper. Dibenzyl Disulfide (DBDS) has been found to be the leading corrosive Sulphur compound in the insulation oil [1]. The process of copper sulphide formation and the deposition in the paper is still being investigated, but a recently proposed method seems to be gaining some confidence [2]. This method suggests 3 options Passivation, oil change and depolarization, besides the Ref. [1] proposes a two-step process; initially the DBDS and some oil soluble copper complexes are formed. Secondly the copper complexes are absorbed in the paper insulation, where they then decompose into copper sulphide [3].

The most commonly used mitigating technique for corrosive sulphur contaminated oil is passivation, normally using Irgamet 39 or 1, 2, 3-benzotriazole (BTA). The passivator is diluted into the oil to a concentration of around 100 ppm, where it then reacts with the copper conductors to form a complex layer around the copper, preventing it from interacting with DBDS compounds and forming copper sulphide, however there are many others methods as polarization, regeneration, oil change, among others.

This research investigates the electrical effects in power and distribution transformers, which have tested positive for corrosive

* Corresponding author.
E-mail addresses: ricardoariasvelasquez@hotmail.com, rariasve@fmi.com (R.M. Arias Velásquez).

https://doi.org/10.1016/j.engfailanal.2018.05.018
Received 12 April 2018; Accepted 27 May 2018
Available online 01 June 2018
1350-6307/

Sulphur, and the evolution of those properties as the asset degrades due to Sulphur corrosion. Finally this paper propose 4 methods with advantages and problems with the solution. Condition monitoring techniques under investigation will include dielectric spectroscopy, DGA, health index (HI), physical, chemistry and electrical test, amongst others. Partial discharge techniques will be investigated, however, the voltage between the coil plates is low and therefore it will not contribute significantly to the overall insulation breakdown, in corrosive oil related faults [4], but the early detection is considered with others factors and results. The goal of this research is to establish key electrical properties in non-passivated for 61 power and distribution transformers that demonstrate detectable changes as the equipment degrades due to the insulation oil being corrosive to prevent a failure in the main component of the high voltage grid [26, 27].

2. Internal assessment

2.1. Reason for corrosive Sulphur in transformers

In the years 1999–2010 onwards there have been a series of unexpected failures and of the same type in power transformers (around 50 cases known worldwide) in a very short period of operation of the equipment (from 7 to 10 years) [1]. They have detected the presence of copper sulfite in the conductors and insulating material. Up to the present the failures have occurred without previous evidence of normal accumulation of combustible gases and that is why the problem is difficult to detect and manage. Corrosion of copper in oil is an expensive industrial problem, particularly in transformers (or bearings) resulting in failures. This damage can occur through dissolved oxygen (or air) [5] or corrosive Sulphur species [6, 7].

The dielectric oil is obtained from the distillation of crude oil. It is here, where sulphur is found as a common element, depending on the oil, there may be tens or hundreds of different sulphur compounds present in the oil, due to the selection of crude oil and refining are the two main factors that indicate the presence of sulfides in the oil, but just a few corrosive sulphur compounds have been identified, of which DBDS is one of them. There are 2 aspects for Sulphur compounds, they play a fundamental role as a natural antioxidant (inhibitors) and give the oil a very good oxidation stability, and however, some “types” of sulphur can cause corrosion to the metal parts of the transformer [8].

Therefore, in the Fig. 1, the oils with sulphur molecules are sulfides in insulating oils = 0.01–0.5% are described in the Table 1, in elemental Sulfides, Mercaptans, Thioesters, Disulfides and poly Disulfides, Triophenes, Dibenzothiophenes, among others [9].

Besides in old transformers the quantity of insulation oil was bigger than the recently transformers, for example in 1915 it was 7.5 oil liters per kVA, and currently is 0.4. [10].

A combination of both factors has been the main cause of the appearance of corrosive sulphur in the transformers, which causes the sudden failure of them.

The process of manufacturing the oil, and the overloads of the transformers accelerate the corrosion process, it is represented in the Fig. 2.

In the Fig. 2, The copper Sulphides is deposited in the active part (copper) and the insulating paper, causing the dielectric strength to decrease and the equipment to end up decomposing or failing.

Finally, the reason for the corrosive Sulphur in transformer are the followings.

- Potentially corrosive compounds in several new transformer oils between 90’s and 2008. In principle, one could say that between 90’s and 2008 almost every manufacturer had one or several oil brands which were corrosive
- Most of these oils contained Sulphur compound Dibenzyl disulphide (DBDS).
- Such oils are potentially corrosive according IEC 62535.
- Formation of corrosive/potentially corrosive Sulphur during unsatisfactory transformer regeneration process.
- Regenerated oils contain one or different kinds of a corrosive Sulphur compounds after the treatment.

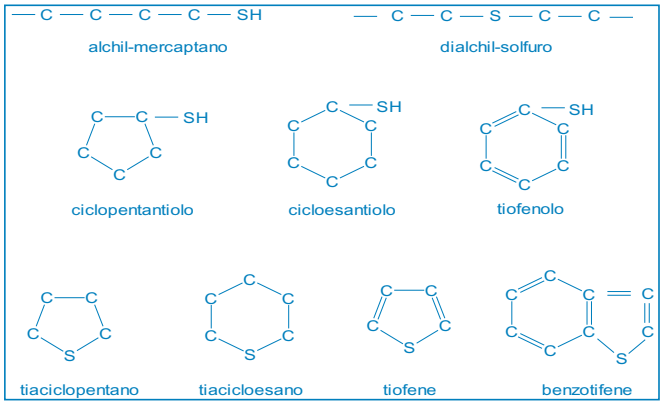

Fig. 1. Chemistry structure for Sulphur.