LIFE-CYCLE ANALYSIS OF TRANSFORMERS OF TRANSFORMING STATIONS AND POSTS

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Abstract: Transformers of electric transforming stations and posts represent the most precious equipments, reason that requires attempts and due prophylactic measurements in order to forecast the life-cycle of transformers. The establishment of the allowable overcharge and of its life-cycle in the rush our of systematical and accidental charge has a specially practical importance for the exploitation of electric transformers of electric transforming stations and posts.

Keywords: life-cycle, charge, electrical insulating materials, factor of thermal improvement, thermal request, high voltage breakdown.

1. INTRODUCTION

During the last year, there were performed many researches concerning the overcharging capacity of transformers of electric transforming stations and posts. After researches, there were elaborated indications and prescriptions that subjectively correlate the overcharge's size with its time, ignoring a series of factors with a decisive role in solving this problem. In the same time, we have to mention that there cannot be established general rules for overcharging electric transformers, these rules being modified from a transformer to another depending on their features.

2. TRANSFORMERS' LIFE-CYCLE

The life-cycle of a transformer is determined by the life-cycle of the insulation imbued with oil that, in fact, represents the electric insulation of its wrappings.

During the exploitation of electric transformers of electric transforming stations and posts, it takes place a depreciation of the physical qualities of electrical insulating materials. This process is named aging process and it is a very complex process performed under the influence of many factors, as: temperature, humidity, oxygen, mechanical requests. Among all these factors, temperature can be influenced through the exploitation of transformers, in the same time it is also the most important factor that ascertains the aging process.

3. AGING OF ELECTRICAL INSULATING MATERIALS

The aging process of an electrical insulating material is characterized by the modification of physical qualities.

The choice of the physical qualities that characterize the aging process of electrical insulating materials, is a notorious problem.

The continuous working time of an electrical insulating material, in which its physical quality, characteristic of aging, reaches the value at which this have to be considered completely used, is named life-cycle. The dependence relationship between life-cycle and temperature represents the rule of electric transformers' life-cycle (1), (2) and it can be mathematically expressed in two forms. For electrical insulating materials we will have:

$$D = \alpha \cdot e^{-\beta\theta} \tag{1}$$

$$D = A \cdot e^{\frac{B}{T}} \tag{2}$$

or

where: D - life-cycle of the electric insulating material
θ - temperature at which the electric insulating material is submitted [°C]
T - temperature at which the electric insulating material is submitted, in K
α, β, A, B – characteristic constants of the electric insulating material

The rule of life-cycle is fundamental from the theoretical point of view. The aging process of electric insulating materials is accompanied by the modification within the structure of the electric insulating material.
For a structural parameter C that characterizes the aging status of an electric insulating material, according to the motive theory of chemical reactions, the variation speed of such a parameter within the chemical reaction that takes place, is straight-proportional with the current value of the C parameter, it means:

$$\frac{dC}{dT} = -KC \tag{3}$$

in which K depends on temperature, according to the relation:

$$K = \lambda \bullet e^{-\frac{B}{T}} \tag{4}$$

Replacing the material constant K in the relation (3) we will have:

$$\frac{dC}{dT} = -\lambda e^{-\frac{B}{T}} C \tag{5}$$

$$\frac{dC}{C} = -\lambda e^{-\frac{B}{T}} dt \tag{6}$$

or

The structural parameter of C will have a new value C_2 for a new status of the electric insulating material, so t = 0. Exposing the electric insulating material at a temperature T, after a certain time D, that represents the life-cycle, the material will be in a degrading status, when the value of the parameter C is C_2.
Integrating the expression (6), we will have:

$$\int_{c_1}^{c_2} \frac{dc}{c} = -\lambda e^{\frac{B}{T}} \int_0^D dt \tag{7}$$

it results that:

$$D = \frac{1}{\lambda} \ln \frac{C_1}{C_2} e^{\frac{B}{T}} \tag{8}$$

Noticing that:

$$A = \frac{1}{\lambda} \ln \frac{C_1}{C_2} \tag{9}$$

where A is the constant of material.

So, we will have:

$D = A \cdot e^{B/T}$

Relation (9) represents just the life-cycle rule.

Life-cycle rules do not allow the practical estimation of the use degree of the insulation of a transformer, from the point of view of thermal aging.

4. ESTIMATION OF USE DEGREE OF A TRANSFORMER INSULATION

Relation (5) expresses the variation speed of the structural parameter C at a certain temperature T. Electric transformers of electric stations and posts have to be exploited so that to ensure a life-cycle of almost 25 years. This life-cycle is resulted by maintaining, for example, the paper insulation of the transformer at a certain constant temperature, well-mentioned, named normal temperature noted with $T_{N.}$

This temperature correspondents to a normal degrading speed of insulation, that can be expressed thus:

$$\left(\frac{dc}{dt}\right)_N = -\lambda e^{\frac{B}{T_N}} C \tag{10}$$

We will define factor of relative thermal aging or factor of relative thermal use, the relation:

$$\rho = \frac{\frac{dc}{dt}}{\left(\frac{dc}{dt}\right)_N} \tag{11}$$

Taking into account the relations (5) and (11) we can write that:

$$\rho = e^{\left[\frac{B}{T_N} = \frac{B}{T(t)}\right]} \tag{12}$$

We can ascertain that the current value of ρ shows the use degree of the electric insulating material, at a given moment. We will distinguish two cases:

- $\rho > 1$, means that, at a given moment, the speed of thermal degrading of the electric insulating material is bigger;
- $\rho < 1$, means that, at a given moment, the speed of thermal degrading of the electric insulating material is smallest than the normal speed

For estimating the use degree of electric insulating materials in a certain period of time Δt, it is defined the relative thermal aging or the relative thermal use u (13), as average value of ρ at the given period, so that:

$$u = \frac{1}{\Delta t}\int_0^{\Delta t} \rho(t)\,dt = \frac{1}{\Delta t}\int_0^{\Delta t} e^{\left[\frac{B}{T_N} = \frac{B}{T(t)}\right]} dt \qquad (13)$$

Relations (12) and (13) define the relative thermal aging of the electric insulating materials afferent to the electric transformers of transforming stations and posts in accordance with the life-cycle rule.

By analogy, we can define these sizes in accordance with the law expressed in the relation (1), thus:

$$\rho(t) = e^{-\beta(\theta_N - \theta(t))} \qquad (14)$$

and

$$u = \frac{1}{\Delta t}\int_0^{\Delta t} e^{-\beta[\theta_N - \theta(t)]} dt \qquad (15)$$

5. CONCLUSIONS

With the help of the attempts and prophylactic measurements made at the powerful electric transformers of electric transforming stations and posts, we can elaborate variation diagrams of certain parameters, as: dielectric rigidity, angular tangency of dielectric losses and the insulation resistance of the electric insulating oil and of wrappings. The study of these parameters with regard to time, offers the possibility to perform revision and prophylactic maintenance services in order to increase the life-cycle and the reliability of electric transformers.

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