Recognition of the benefits by the use of Transformers and Reactors immersed in insulating fluid with high fire point (K Class): the case of Fire Department of Sao Paulo state in Brazil

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SUMMARY

The new Technical Instruction n° 37/2018 Electrical Substation, from the Fire Department of São Paulo state, Brazil, complemented by standard ABNT NBR 13231 - Fire Protection in Electrical Substations, establishes new fire safety measures in electric substations, complying with the Fire Safety Regulations of buildings and risk areas of São Paulo state. It brings fire protection practices in electrical substations that improve the procedures and incorporate new fire safety prevention and control technologies. This work presents the main requirements of Technical Instruction n° 37/2018 related to the use of insulating fluid with high fire point (K-Class fluid) and resulting benefits for the design, construction and operation of electrical substations, without, however, loss of the fire safety margin.

KEYWORDS

K-Class Fluid - High Fire Point - Fire Protection - Electrical Substation Design - Fire-Wall - Oil Containment System - Fire Extinguishing System – Insulating Fluid - Natural Ester

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1 - INTRODUCTION

A Technical Instruction (TI) is a technical document prepared by the Fire Department that regulates fire safety measures in buildings and risk areas. TI-37 from the Fire Department of the Sao Paulo state, Brazil, establishes fire safety measures in electric substations, in compliance with the Fire Safety Regulation of buildings and risk areas of Sao Paulo State [1].

With its issuance in March 2018, TI-37 applies to all types of dry and oil-immersed electric substations, and is complemented by the Brazilian standard ABNT NBR 13231 - Fire protection in electrical substations. It updates practices and enhances fire safety procedures at electrical substations. In particular, the TI-37 incorporates the technology application of high fire point insulating fluid (K-Class fluid) [2].

2 – K-CLASS FLUID

For classification as K-Class, a fluid must have a fire point equal to or greater than 300°C in an open cup. The official inclusion of K-Class in the US National Electrical Code (NEC) occurred in 1978, and up to 1984, these insulating fluids were known as "high fire point liquids" or "fire-resistant fluids" [3].

The 1981 edition of NEC required the K-Class fluids certification issued by independent parts and the insurance company Factory Mutual (FM) was the first accredited testing laboratory to certify K-Class fluids in transformers [4]. In 1984, the combination of less flammable fluids was introduced by Underwriters Laboratories (UL) [5].

K-Class fluids offer significantly better fire resistance than the conventional mineral oil with a typical fire point of 160°C. Tests confirm the ability of all K-Class fluids to reduce the initial intensity of a catastrophic disaster in a transformer and to prevent a fire. A history of more than forty years of fire safety for K-Class insulation fluids confirms that a fire point above 300°C is high enough to allow that new fire safety measures can be established at electrical substations.

3 - NATURAL ESTER AS AN OPTION OF K-CLASS FLUID

The use of natural ester as insulating fluid in transformers has grown worldwide over the past twenty-three years with established units today surpassing 2 million [6]. The natural ester insulating fluid that complies with ABNT NBR 15422 [7], besides being classified as K-Class fluid, still presents environmental advantages due to its readily biodegradable characteristic. The use of natural ester insulating fluid in place of mineral oil in reactors and power transformers, also promotes the extension of the insulation life, due to the reduced paper degradation, and enables an increase of the loading capacity [8].

4 - HIGHLIGHTS OF TI-37 IN THE RECOGNITION OF K-CLASS FLUIDS

4.1 - Basic Requirements for Fire Protection - Fire Wall (item 5.4.4.2 and 5.4.4.3)

Items 5.4.4.2 and 5.4.4.3 determine that, for buildings and equipment, when the free distance of physical separation meets Tables 1 and 2, or when the free distance of physical separation is greater than 15m, there is no need to separate them by interposing a fire-wall. It is important to note that, in case of mineral oil, the reference to be considered for distance is the inner edge of the oil containment system. But, in the case of K-Class fluid, the distance is

considered from the components of the transformer that can be pressurized, including bushings, tank, conservator, radiators and on-load tap changer tank.

Table 1 : Minimum separation distances between transformers and buildings

Type of transformer insulation fluid	Insulating fluid volume (liters)	Minimum horizontal distance (dimension X or K of Fig. 1)		
		2 hours fire-resistant building (m)	Non-combustible building (m)	Combustible building (m)
Mineral oil	< 2.000	1,5	4,6	7,6
	> 2.000 < 20.000	4,6	7,6	15,2
	> 20.000	7,6	15,2	30,5
Insulating fluid with high fire point (K-Class)	< 38.000	1,5		7,6
	> 38.000	4,6		15,2

Table 2 : Minimum separation distances between transformers and adjacent equipment

Type of transformer insulation fluid	Insulating fluid volume (liters)	Distance (m)
Mineral oil	< 2.000	1,5
	> 2.000 < 20.000	7,6
	> 20.000	15,2
Insulating fluid with high fire point (K-Class)	< 38.000	1,5
	> 38.000	7,6

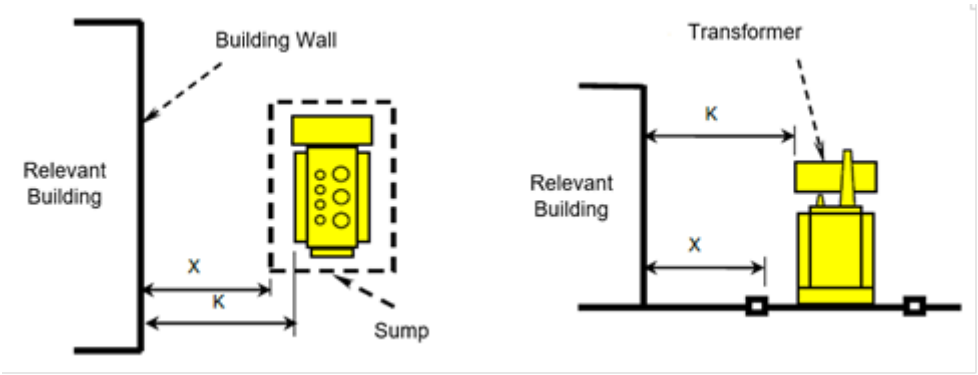

Figure 1 : Oil-immersed transformer externally installed

4.2 - Basic Requirements for Fire Protection - Automatic fixed system for fire protection (item 5.4.5.5)

This item determines that, when an automatic fixed system is provided for the protection of power transformer and reactors, it must be in accordance with ABNT NBR 13231 [9], which in turn, only specifies it for equipment with mineral oil. In case of power transformers and reactors using K-Class fluid, there is no need to install an automatic fixed system in the substation.

5 - HIGHLIGHTS OF TI-37 IN THE RECOGNITION OF K-CLASS FLUIDS TYPE NATURAL ESTER

5.1 - Basic Requirements for Fire Protection - Oil containment system (item 5.4.5.4)

This item determines that, when using K-Class insulating natural ester fluid that meets the biodegradability and toxicity criteria of ABNT NBR 13231, the power transformers and reactors, under the approval, may dispense the use of the oil containment system with drainage system interconnected to the containment box (water/oil separator) and may use a simplified oil containment systems through dikes, as shown in Fig. 2.

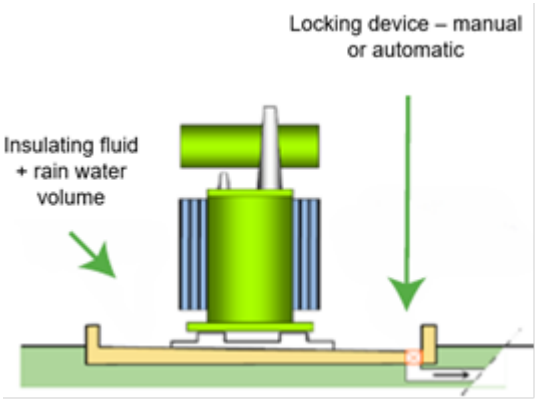

Figure 2 : Example of simplified oil containment systems

6 - CASE STUDIES

Two cases studies are present in this paper exemplifying the application of the TI-37 and the benefits by the use of transformers and reactors immersed in K-Class insulating fluid.

6.1 – Case Study 1 – An Existant Substation

A case study was carried out by a substation design company using the TI-37. An existing substation, as shown in Fig. 3, composed of 2 banks of single-phase 500 kV shunt reactors, plus 01 reserve unit (totaling 7 units, with insulation vegetable oil volume <38,000 liters each) was redesigned by applying TI-37 concepts. As a result, significant advantages were obtained:

- Elimination of 6 fire walls
- Elimination of 7 oil containment systems

• Reduction of the length of the shunt reactors area from 70 m to 50 m (- 30%)

As an economic result of this case study, there was a 20% reduction in the cost of civil works (materials and labor) in the comparison with the substation design with shunt reactors with mineral oil.

Figure 3 : A real substation with 7 shunt reactors with mineral oil used as reference for TI-37 case study

6.2 – Case Study 2 – New Urban Area Substation

An electric power utility that serves the metropolitan region of São Paulo, sought a way to compact substations installed in urban areas. Faced with a new substation project that needed to serve approximately 20,000 consumers in the city of Guarulhos - SP, this urban facility had the following requirements:

- 2 three-phase transformers of 20 MVA, 69 kV
- Inserted in a populous neighborhood
- Need to increase fire safety
- Need for noise attenuation
- Bay enclosed

Several technical solutions were adopted to favor the compact design of the substation, as shown in Fig. 4, but the one that provided most of the gains was the use of natural ester fluid (K-Class) in the power transformers. The use of K-Class natural ester fluid allowed the reduction of the land area of 2,500 m² (in the design with the use of mineral oil fluid) to 1,015 m². The cost of the land fell from R$ 5,000,000.00 to R$ 2,000,000.00.

Figure 4 : The substation inserted in a populous neighborhood and the assembly of power transformers with using the benefits of TI-37.

7 - CONCLUSIONS

The new Technical Instruction N° 37/2018 Electrical Substation, from the Fire Department of São Paulo state in Brazil, complemented by the standard ABNT NBR 13231 - Fire Protection in Electrical Substations, of 2014, recognizes that transformers and power reactors immersed in K-Class insulating fluid, provide better utilization of the substation installation area by reducing the distances between equipment and buildings, by eliminating the use of fire walls and by eliminating the use of automatic fixed fire extinguishing systems. It also recognizes that, when using K-Class insulating fluid type natural ester, it is possible, in addition to the advantages already mentioned, to further simplify the oil containment systems.

The application of preventive solutions that incorporates new technologies, new materials and new fire safety practices, such as the use of high fire point (K-Class) insulating natural ester recognized by TI No. 37/2018, provides economic benefits to the project, to the construction and to the operation of electrical substations, without loss of fire safety margin.

8 - BIBLIOGRAPHY

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