A STUDY ON THE RISK PROTECTION OF THE MOLD TRANSFORMER

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Abstract

This paper investigates and analyzes the installation and failure status of mold transformer being used in domestic subways and describes the extinguishing process by time through the combustion test of winding part of mold transformer.

Condition of installed mold transformers and classes of fire were surveyed and the mold transformer was burned in a horizontal heating furnace. It was confirmed that the mold transformer is self extinguishing and nonflammability. According to this results, the suitable standard of fire protection for the mold transformer was demanded after review of domestic and abroad law.

It is expected that the cost of fire protection equipment can be reduced by using the status and combustion test result of mold transformer.

Introduction

Recently, the safety measurement of electric installation in becoming high-density the urban area has become more strict over the years. In the past, if the non-flammability was required in the transformer that is in charge of important role in safety of the distribution system, askarel, silicon oil and wanis dry-type transformers were used. However after the transformers using insulating oil were prohibited because of the environmental safety, the maintenance and the inspection of the wanis dry-type transformer from the old class has become more strict than the oil transformers. Thus, the number of non-flammable dry-type transformer with low maintenance and no insulating oil has been increasing.

Because the mold transformer's winding part is casted in the epoxy resin, it has the non-flammability. In addition, by using the high-insulating epoxy resin, it is possible to have lower size, weight and noise level than that of the wanis dry-type transformer as well as enhancing much more electrical and mechanical characteristics. Because of these advantages considerable amount of favored comments were received after the mold transformer has been introduced, and now the increasing demand of mold transformers are being expanded in the power supply facilities such as subways, large buildings and others as a substitute.

The advantages of the mold transformer are as follows;

1) By charging and compounding inorganic substance such as silica into the solid insulation mainly made of epoxy, it has non-flammability.
2) By having high-voltage and low-voltage windings casted with each resin, it is mechanically strong and it is powerful against short-circuit current to resist instantaneous short-circuit of secondary winding.
3) Because of its large thermal capacity and temp. rise time constant of winding, short-time overload capacity is large.
4) The insulation distance between windings is shortened and the insulation structural layer has become thin, making the whole structure compact-sized. The weight is lighter because the winding and the surrounding area excluding solid insulation materials are made up of air instead of oil.
5) It is possible to lower the loss produced in the iron core and the winding, because the whole transformer is compact-sized and light.
6) Because the noise generated by iron core is sound-insulated by mold winding, the noise can be reduced, comparing to the wanis dry type transformer.
7) Because the winding and other components are casted with low-absorbing epoxy, it has excellent property in dust-proof and damp-proof. Also, it is not greatly effected by the surrounding circumstances and after having resting period of operation for a long time, it is easy to operate and its maintenance is simple.

Recently, in case of the mold transformers that keep going on increasing in demands and are replacing the oil transformers, the fire-related safety standard and regulations based on the oil transformers are still being enforced. Although the mold transformer has numerous advantages over the oil transformer, because the safety facility standard is based on the standard of the oil transformer unnecessary guarding requirements are expected to increase.

Thus this paper will research and analyze the failure of the mold transformer which holds most of the nationally reported accidents. By analyzing the fire extinguishing characteristics of mold transformer through combustion test, this paper will emphasize the necessity of establishment of the fire-related regulations used in the domestic and abroad substation.

Status of Oil Transformer and Mold Transformer for Subway

Failures and installation of transformer for subway

In case of transformer for rectifier, from 77 total number of oil self-cooled transformers there were 2 cases of accidents reported. However, from 51 mold transformers there were 49 cases of accidents, which

means that almost all of them had a failure. In the case of high-voltage distribution transformer, from 28 oil self-cooled transformers only 1 failure occurred, while from 15 mold transformers installed there were 16 failures occurred which stated that there were more failures than the number of transformers installed. These results are shown on table 2-1.

Table 2-1 Failure as types

Types	Transformer for rectifier		High-voltage distribution transformer		
	No. installed(set)	No. failed(case)	No. installed(set)	No. failed(case)	Remarks
Total	128	51	43	17	
Oil self-cooled type	77	2	28	1	
Mold type	51	49	15	16	one set more than 2 failures

The installation and failure according to the lines, in case of transformer for rectifier, from 49 installations of line B there were 47 failures which caused most number of accidents. In the line C the problems were preserved and not even one failure occurred. In case of high-voltage distribution transformer, again same with the transformer for rectifier, from 14 installation of line B there were 15 failures. After the problems were preserved line C and line D, there was no failure occurred even one. These results are shown on table 2-2.

Table 2-2 Failure as lines

Line No.	Transformer for rectifier		High-voltage distribution transformer	
	No. installed(set)	No. failed(case)	No. installed(set)	No. failed(case)
Total	128	51	43	17
Line A	9	2	3	2
Line B	49	47	14	15
Line C	38	-	14	-
Line D	32	2	12	-

The number of annual failure in case of transformers for rectifier, every year least one and up to 7 failures occurred. There were annual average of 4 failures and in case of high-voltage distribution transformer average of one failure occurred annually. These results are shown on table 2-3.

Table 2-3 Annual failure

year	classification	total	'83-'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96
No. failed	Transformer for rectifier	51	11	4	1	6	3	3	2	2	5	7	3	4
	High-voltage distribution transformer	17	6	3	-	1	1	1	-	1	1	-	3	-

Analysis of subway transformer failure causes

The following are the results of analyzing the failure causes of the subway lines from A to D in city A.

a. The testing subway's load during rush hours in the morning and the evening were recorded to be 200% peak of the normal load. In case of the overload, because of the change of stress caused by electromagnetic force of the transformer the great level of noise and vibration were accompanied.

b. In the city A the initially-installed mold transformers, both domestic and foreign made, were replaced because of the failure during operation(specially in the case of vacuum impregnation type it was almost 100%). Because even the high standard foreign products were not exceptional, the cause is not by the inner void or the fault of the manufacture, but by the repeated change of stress in the winding and iron core during overload. This causes the crack and as the crack becomes larger and larger it is estimated to produce the breakdown of the insulation.

c. In the case of the examined broken mold transformer, during the moment of failure it did not lead to other bigger failure such as fire and it is concluded to have no problem concerning fire.

Combustion test

Specimen

The specimen was tested with high-voltage winding of distributing ultra-high voltage single-phase mold t ransformer rated 50 [kVA], and the table 3-1 shows the specification of the specimen.

Table 3-1 Specification of specimen

Class.	Specification				Ingredient of specimen				
	O.D	I.D	H.	T.	resin	hardener	flexibilizer	accelerator	color paste
Spec.	380㎜	314㎜	640㎜	31㎜	CY205(Araldite F)	HY905	DY040	DY062	DW0133(red)

Testing method

Place the specimen on a horizontal heating furnace as shown in the Fig. 3-1. The specimen was heated horizontally until it is initially ignited as the heating temperature curve in the Fig. 3-2 meeting the requirement of the fireproof testing method (hereinafter referred to as KSF 2257) of the construction structures. When the initial ignition has been checked visually, stop the heating and measure the time taken for the flame on the specimen to be completely burned. After the flame on the specimen has completely burned, apply the heating again and measure the time taken to completely burn the specimen. The horizontal heating furnace used in this test has been shown in the Fig. 3-1 and the specimen was

installed inside of the horizontal heating furnace as shown in the Fig. The positions of the thermoelectric couple used to measure the temperature inside of the horizontal heating furnace has been shown as ① through ⑨. The inner wall of the horizontal heating furnace is made up of fireproof bricks with the characteristic to resist high temperature. After installing the specimen in the horizontal heating furnace, cover the upper part with the fireproof covering of the same material. Also by filling the space between the horizontal heating furnace and the fireproof covering with the fireproof fabric, the heat escape has been protected. In the combustion test, to meet the curve of the test specified in KSF 2257, it is being controlled by integrated system that the temperature is controlled automatically. When if there is no requirement for the integrated system, the horizontal heating furnace is to maintain a temperature of 1025 ℃ after a certain time. In the Fig. 3-2 the heating temperature curve is shown.

Testing process

Step 1 : As a preparative step for the combustion test of a mold transformer, the inner space of the horizontal heating furnace is cleaned and the states of combustion burner and other equipments are identified. The separated high voltage part(hereinafter referred to as specimen) of mold transformer is put inside of the horizontal heating furnace, and the combustion place is determined. Protective blocks are piled up for proper photographing of combustion, and outward heat dissipation is prevented by inserting fireproof fabric. Then the outer equipment for combustion test by covering all parts of the horizontal heating furnace with upper cover is constructed, and gasoline used as fuel for the combustion burner is injected into a fuel tank. The state of specimen, before firing, with combustion burner is shown in Fig. 3-3.

Step 2 : After Step 1 is completed, Step 2 which is the initial step of regular combustion test is performed. After making sure that the gasoline is injected into a fuel tank, this step is performed. It is correspondent to an intersection point of X-axis and Y-axis on the combustion test curve, shown in unitification system of the horizontal heating furnace. After combustion burner of horizontal heating furnace is ignited, the state of specimen is visually examined for the first time. This is shown in Fig. 3-4.

Step 3 : Partial ignition is examined initially in 6 minutes and 10 seconds after the flame is examined at combustion burner. The trace that is burned black is observed only at the upper part of specimen. The state of specimen at this time is shown in Fig. 3-5.

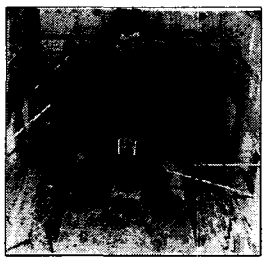
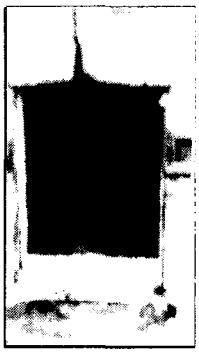
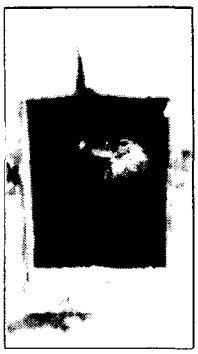
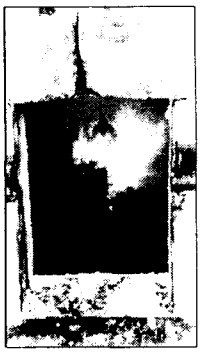
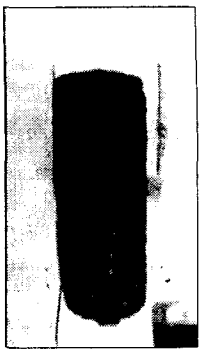

Fig. 3-3 Fig. 3-4 Fig. 3-5 Fig. 3-6 Fig. 3-7

Fig. 3-3 State of specimen before firing

Fig. 3-4 State of specimen when firing by burner

Fig. 3-5 Partial ignition at the upper end of specimen

Fig. 3-6 State of specimen just before stopping the provision of flame source

Fig. 3-7 State of specimen just after the flame of the upper part of specimen

Step 4 : It is observed that the flame is spread over a quarter of the specimen from the top in 50 seconds after partial ignition is examined. Here, the time of self fire extinguishing when the specimen is partially ignited is measured by extinguishing the combustion burner. According to the above mentioned results, we know that the flame spread rapidly upon the specimen if the flame is provided continuously. The state of specimen just before stopping the provision of flame source of combustion burner is shown in Fig. 3-6.

Step 5 : The flame of specimen is extinguished entirely in 19 minutes and 25 seconds after blocking the provision of flame source of combustion burner. The trace of carbonized black at the upper part of specimen is observed. The specimen state just after the upper part flame of specimen has been extinguished entirely is shown in Fig. 3-7.

Step 6 : The ignition of inner combustion burner of horizontal heating furnace is examined by preparing the repeated heating measurement of entire combustion time and entire extinguishing time of specimen for 55 seconds after entire extinguishing is examined. Afterthat, partial ignition at upper part of specimen is observed again in 2 minutes and 10 seconds. This flame spreads over specimen in a minute after partial ignition is examined. By this result, the rapid velocity of the continuous provision spreading flame can be examined again. The state of flame is spreading over specimen is shown in Fig. 3-8.

Step 7 : Entire combustion of specimen is examined in 74 minutes and 30 seconds after the flame has spread over all surface of specimen by the control of combustive unification system. This system distinguishes whether or not the entire combustion is made by the gas generated during the burning of

specimen. By the way, at this time, the flame on the specimen surface is not visually observed, and the flame source is extinguished. The state of specimen just before the provision of flame source has stopped during the entire buring of specimen and it is shown in Fig. 3-9.

Fig. 3-8

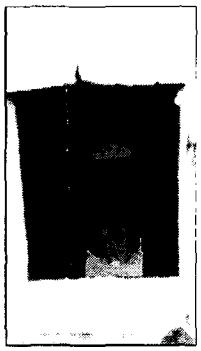

Fig. 3-9

Fig. 3-8 State when the flame is spreading over specimen

Fig. 3-9 State of specimen just before the provision of flame source is stopped when the specimen is burned entirely

Each measurement results of heating temperature in horizontal heating furnace from Step 1 to Step 7 as mentioned in the above results above is shown Table 3-2.

Table 3-2 Measurement of heating temperature and time · temperature area

Time [min]	KSF 2257 Furnace Temperature [℃]	Actual Furnace Temperature [℃]	Area under standard curve [℃ min]	Area under actual curve [℃ min]	Difference [%]	Tolerance (+ or -) [%]
0	20	11				
2	220	195				
4	440	438				
6	600	494				
8	665	479				
10	705	245				
20	795	56				
40	880	875				
60	925	926	45833	30297	-33.90	10.00
90	980	974				
100	990	1005				
104	994	997	87407	71667	-18.01	7.50

Results

As a result of grasping the combustion characteristic by performing the 2-hour heating test, applying the testing method of KSF 2257 to the ultra-high voltage mold transformer, the initial ignition time of the same specimen takes 6 minutes, and self extinguishing time takes 19 minutes. Aftrethat, secondary heating is applied, and entire combustion time by heating takes 78 minutes.

By performing this test, the extinguishing characteristics of specimen are analyzed.

Conclusion

The following conclusions are acquired by these experimental results and status of mold transformer.

(1) In the combustion test of specimen of mold transformer at horizontal heating furnace, epoxy resin is ignited and the provision of flame source is stopped from a combustion burner. In the test, the specimen flame is self extinguished entirely in 19 minutes and 25 seconds under the inner temperature of horizontal heating furnace over 1025[℃]. Therefore it is examined that the epoxy resin of mold transformer has non-flammability and self extinguishing characteristic.

(2) Based on the status of transformers for subway and the combustion test results of mold transformer, the propriety that extinguishing installation must be equipped by distinguishing mold transformer from oil transformer is ascertained, furthermore, according to above-mentioned, it is proved that the standards for economic fire-fighting equipment to be applied to Fire proof Act have to be urgently established.

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