TECHNOLOGIES FOR TOMORROW

Improvement for Diagnosing Internal Abnormalities in Oil-filled Transformer

1. Introduction

The dissolved gas analysis process is among the most widely practiced methods of diagnosing internal transformer faults. A mix of dissolved gas extraction technology and gas chromatography; the process has been verified as an effective way of localizing internal transformer faults; with large volumes of supporting data collected from field testing to obtain reliable long term target gas analysis technology.

The traditional dissolved gas analysis method of identifying fault modes and troubleshooting helps distinguish between discharge and overheat modes, but performs less well in localizing faults between the winding and iron core that could lead to a transformer shutdown.

Faults occurring in the iron core empirically account for more than 90% of the causes of gas generation. Faults in the winding should require immediate intervention because they could develop into dielectric breakdown accidents. Further, because faulty transformers need to be brought into shops for internal checks and repairs, their extended periods of unavailability used to bother the workshops in charge of their maintenance.

A gas generation test has been conducted on full-scale models to devise a method of locating overheated parts using data collected by the former method. The traditional dissolved gas analysis process has been coupled with this method to obtain potentially improved accuracy with which to locate overheating in transformers.

2. Development of Overheating Abnormality Diagnostic Methods

Three winding and four core models were selected as experimental models(an example is shown in Fig.1), with reference to those events that were undetectable by external diagnostics, such as on-site electrical testing, among the problems reported by Japanese utilities and previous gas generation incidents.

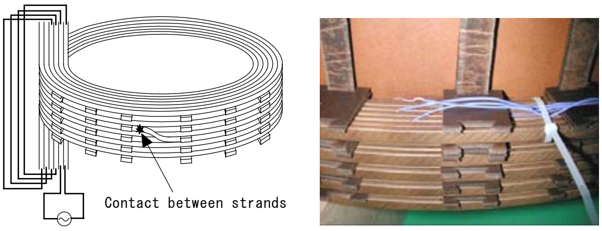

Fig.1 Helical winding model

Accordingly, the component ratio of C_2H_6 (ethane) to C_2H_4 (ethylene) was determined with regard to each set of experimental data, the equivalent overheating temperature and area respectively were estimated by solving the following equations:

- Estimation of equivalent overheating temperature T

$$T=320\times\log (C_2H_4/C_2H_6) + 530$$

- Estimation of the equivalent overheating area S

$$S= (Qoil\times C\times 10^{-3}) / (30\times 24\times K)$$

where
Qoil:Transformer oil volume (Lit)
C:Rate of rise in the total combustible gas (TCG) (ppm/month)
K:Rate of gas generation ($ml/cm^2\times h$)

The rates of gas generation are:

$\log(K)=14 - 12000/(T+273)$ $\quad T > 562$
$\log(K)=5.5 - 4900/(T+273)$ $\quad 562 > T > 285$
$\log(K)=1.2 - 2500/(T+273)$ $\quad T < 285$

The equivalent overheating area of each model was worked out by solving the above equation and then plotted along the abscissa of the horizontal axis in a graph shown in Fig. 2, with the C_2H_4/C_2H_6 ratio along the ordinate to review characteristics of the process of gas generation in the model.

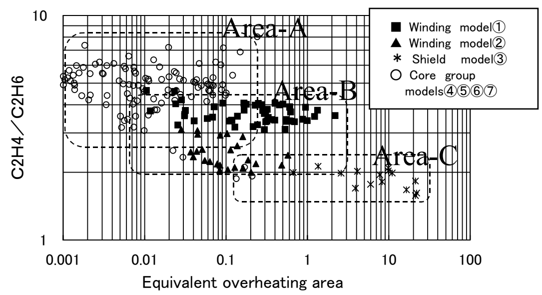

Fig.2 C_2H_4/C_2H_6 ratio and equivalent overheating areain experimental model

Transformers that had previously generated dissolved decomposition gases in overheat mode, with the causes of such gas generation identified by either internal checks or overhauls, were subjected to similar analyses to the experimental models.

Fig. 3 plots data obtained with these transformers in a graph of the equivalent overheating area and the C_2H_4/C_2H_6 ratio as in Fig2.

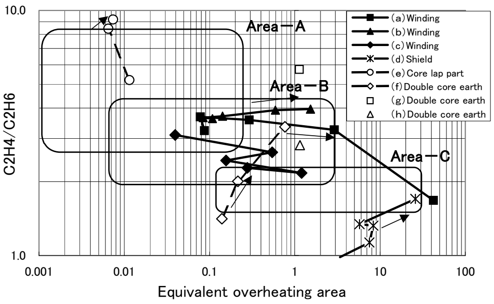

Fig. 3 C_2H_4/C_2H_6 ratio and equivalent overheating area in past examples

A small nunber of data is available on actual transformers but essentially correlates with the experimental models in terms of the rate of gas generation from the winding group. Also with the core group, the rate of gas generation from their tank magnetic shields resulting from core sheets falls within the same range as in the model experimental findings.

Based on the latter, the transformers tested were found to be in good agreement with past records, except for double-earth core modes.

3. Application to Diagnostics

Diagnostics were carried out in diagnostic diagrams as delineated in Fig. 4; based on model experimental findings. Gas analysis data from actual equipment was plotted to find out where faults were located; the core or the winding.

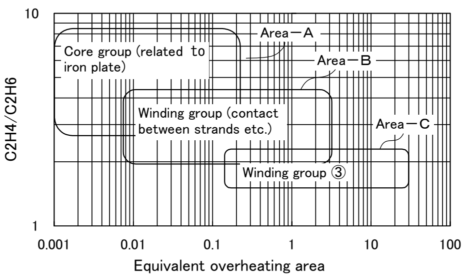

Fig. 4 Diagnostic figure by the ratio of C_2H_4/ C_2H_6 and equivalent overheating area

Based on the model experimental findings and gas analysis data on actual equipment, gas generation trends also provided criteria that aided in distinguishing faults between core and winding-group transformers. Trends in the rate of gas generating relating to the iron sheet in a core group transformer highlighted a smaller equivalent overheating area.

To distinguish faults between core and winding-group transformers, a diagnostic table was prepared in a combination of equivalent overheating area thresholds by breaking down the gas generation trends into four categories. Table1 shows an example of the diagnostic table.

Table 1. Diagnostic table based on gas trend.

		Gas trend			
		Rate of rise is constant	Stop after rapid rise	rapid rise at some point	Rate of rise expands guradually
Equivalent overheating area	Under a constant number	High possibility of iron core group faults	High possibility of iron core group faults	High possibility of iron core group faults	Incipience of winding group or an iron core group faults
	Over a constant number	Possibility of winding group or double core earth faults	Possibility of double core earth faults	Possibility of winding group or double core earth faults	High possibility of winding group faults

This diagnostic method has been applied from May 2003, as a result of internal checks of seven transformers that had demonstrated increases in the total combustible gas, six transformers were daignosed correctly.

A correct diagnostic example as winding faults is shown in Fig.5 and Fig.6. A main cause of a wrong diagnostic example was the overheating of the core group through several sheets of insulating papers. It is a problem in the future.

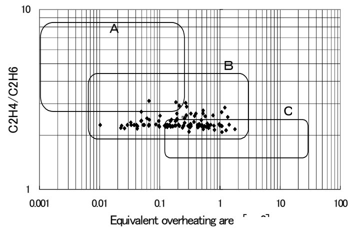

Fig. 5 The diagnostic of Actual transformers

Fig. 6 The inspection of an actual transformer

4. Conclusion

The model experimental findings, coupled with gas analysis data on actual transformers, indicated that core and winding-group transformers yielded different sets of trends in their rate of gas generation, equivalent overheating areas and C_2H_4/C_2H_6 ratios; even when they generated gases in overheat mode, suggesting a diagnostic method useful for enhancing the accuracy with which to locate overheats in transformers.

This practice will not only prevent accidents in electrical power systems for enhanced system reliability and promise enhanced economics through the implementation of optimally timed repairs but will also allow better utilization of assets.

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