Lifetime Evaluation for Distribution Transformers with Over Loaded Condition

Background

Due to a recent cost reduction request and equipment investment suppression in the electric utility, more effective utilization of electric power apparatus is intended. Distribution transformers, such as pole transformers, are also required to be more effective, and an overloaded operation in a short time is tried. But the overloaded operation causes unexpected temperature rise and there is a possibility that severe thermal conditions shorten the lifetime. Therefore, an appropriate lifetime evaluation method is needed. There are so many distribution transformers that an approach of diagnosing each transformer is not realistic, but *1lifetime evaluation based on numerical calculation is anticipated.

Objectives

To develop a calculation method for thermal hysteresis in a distribution transformer considering its load and weather condition, and to analyze degradation characteristics of the insulating paper in high temperature, and to propose the lifetime evaluation method for distribution transformers in overloaded condition.

Principal Results

1. Transient temperature calculation method for distribution transformer considering load and weather condition

By assuming a distribution transformer to be *2three or four stages ladder circuit with thermal resistance and thermal capacity, the transient temperature calculation programs considering load, atmospheric temperature, sunshine and wind were developed. They can be easily executed on a personal computer. A screen image of the program for pole transformers is shown together with thermal equivalent circuit in Fig.1. The results of temperature rise experiment by an actual pole transformer and corresponding calculation are shown in Fig.2.

2. Prediction method of the average polymerization degree of insulating paper considering thermal hysteresis

Accelerated thermal degradation tests of insulating paper under the same atmosphere and components as the actual pole transformer were conducted, and the relationship between heating time and *3the remaining rate of the average polymerization degree was obtained (Fig.3). From this result the experimental equation to evaluate reduction of the average polymerization degree by considering temperature and duration time was constructed, and the prediction method for the average polymerization degree by considering thermal hysteresis was proposed.

By using them together, it is possible to evaluate lifetime of distribution transformers considering past load condition and future operation plan through the prediction of the average polymerization degree and mechanical strength of insulating paper. One evaluation example is shown in Fig.4.

Future Developments

Lager capacity transformers (transformers in distribution substations) will be examined by this method. And besides insulating paper evaluation, thermal degradation of other parts, such as rubber packing, will be investigated.

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Reference

T. Ito, et al., 2000, “Study on calculation method for transient temperature rise of pole transformer with overloaded condition”, Technical Report W99033 (in Japanese)

Y. Mizutani, et al., 2001, “Study on prediction method of thermal deterioration of pole transformer with overloaded condition”, Technical Report W00031 (in Japanese)

Y. Mizutani, et al., 2003, “Calculation Method for Transient Temperature Rise of Distribution Transformer under Overloaded Condition”, Technical Report W03001 (in Japanese)

T. Takahashi, et al., 2005, “Transient temperature calculation method for overloaded pole transformer in consideration of weather condition”, Technical Report H04015 (in Japanese)

＊1：There is a criterion of transformer life based on mechanical strength degradation of insulating paper.

＊2：Pole transformers: three stages, transformers with housing (such as on-street type); four stages

＊3：The average polymerization degree is one characteristic of paper and corresponds to the mechanical strength.

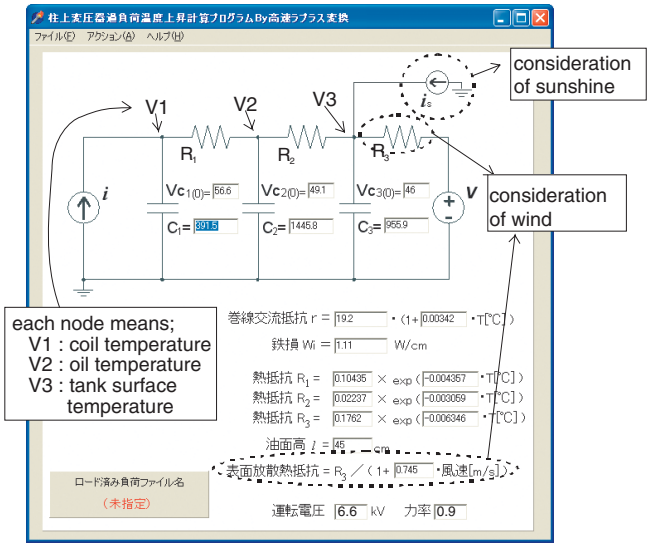

Fig.1 Transient temperature calculation program for pole transformers (Japanese version)

Pole transformer is assumed to be the thermal equivalent circuit shown in this figure. By considering arbitrary load, atmospheric temperature, sunshine and wind, temperatures of the coil, the oil and the tank surface are calculated.

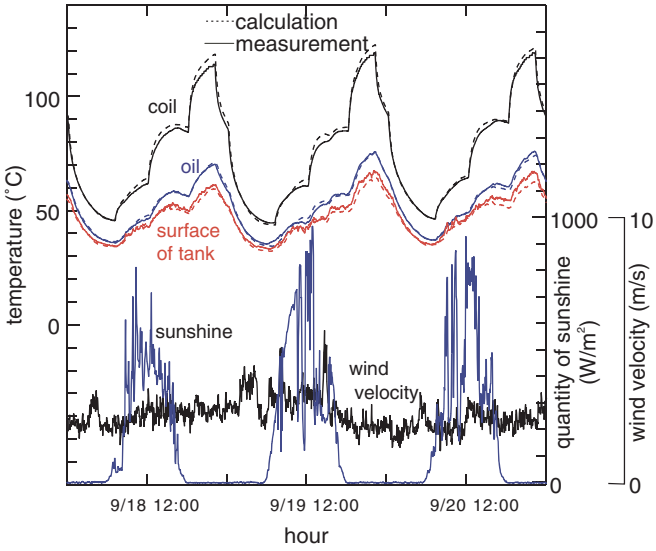

Fig.2 Results of temperature rise tests and calculation of actual pole transformers

Temperature rise tests have been done with a certain load pattern in a day by actual pole transformer. Each temperature agrees with calculation results of the program shown in Fig.1.

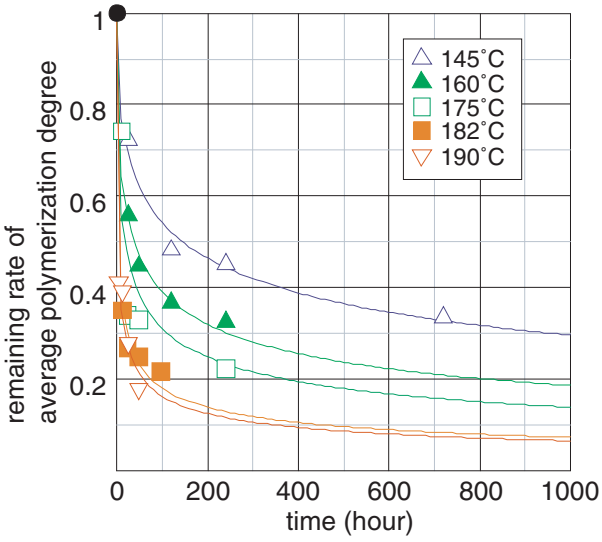

Fig.3 Accelerated thermal degradation tests results of insulating paper

Accelerated thermal degradation tests of insulating paper under the same atmosphere and components as the actual pole transformer have been done, and a change on standing of mechanical strength has been obtained. From the results, experimental equation to evaluate the average polymerization degree by considering temperature and duration time has been constructed. By accumulating the calculations, the average polymerization degree with arbitrary thermal hysteresis can be calculated.

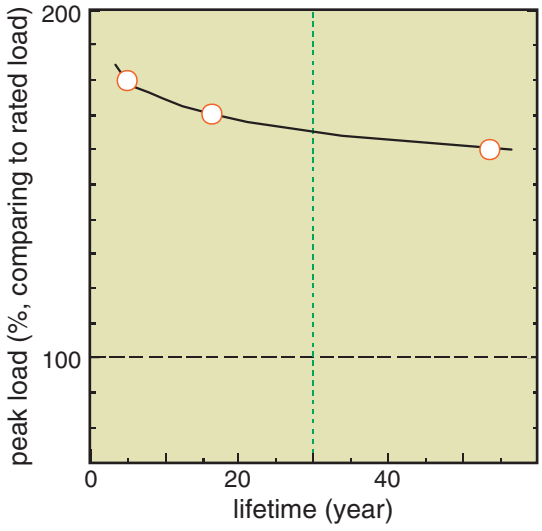

Fig.4 Lifetime evaluation example of over loaded pole transformer

One example of lifetime evaluation of an over loaded pole transformer. A certain load pattern in a day and in a year has been assumed and its peak value in a year has changed, and the mechanical strength has been evaluated through the hysteresis of the maximum temperature of insulating paper (= coil temperature). In this case, the peak duration is short enough, therefore overload edoperation is possible.