EXPERIMENTAL STUDY ON THE LARGE POWER TRANSFORMER UNIT TEMPERATURE VARIATION

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Sistemele de monitorizare a unităților de transformare sunt realizate, după cum spun producătorii acestora, conform ghidurilor de încărcare. Problema care apare se datorează faptului că, modelele termice din diversele versiuni ale acestor ghiduri de încărcare nu furnizează rezultate similare. Astfel, pentru aceeaşi unitate de transformare există posibilitatea de a obține valori divergente în cazul folosirii mai multor tipuri de instalații de monitorizare. De aceea, este necesară o comparație între valorile furnizate de aceste sisteme de monitorizare şi modelul termic din standard. Un alt aspect, la fel de important, îl constituie parametrii modelului termic, parametrii ce ar trebui specificați de către fabricantul unității de transformare.

Lucrarea prezintă o instalație mobilă realizată cu scopul de a realiza aceste măsurători, precum şi rezultatele obținute pentru două unități de transformare de 200MVA.

The monitoring systems of the transformer units are developed according to their loading guides, as their manufacturers specify. The problem that arises is due to the fact that the thermal models of the diverse versions of the loading guides do not yield similar results. Therefore, different values may be obtained for the same transformer unit with different monitoring systems. That is why the values provided by these systems and the standard thermal model should be compared. Another aspect, as important as the previous one, refers to the thermal model parameters that should be specified by the transformer unit manufacturers.

The paper presents a mobile installation that was developed to perform these measurements and the results obtained on two 200MVA power transformer units.

Keywords: power transformer unit, temperature modeling, data acquisition, virtual instrumentation

1. Introduction

The degree the large transformer units are equipped with on-line monitoring systems differs a lot, many of the older monitoring systems being taken out partially or entirely from operation.

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The existing monitoring systems are quite different, both relating to their construction (different manufacturers) and the functions they have to carry out.

The installation performances are based on different standard requirements (IEC 60076-7, IEEE C57.91, etc.). Each standard has a different algorithm which provides different results, so the indications of the monitoring systems are influenced by the implemented algorithm. In most of the cases the manufacturers do not specify the algorithm or the standards they used for the software development. Sometimes, the respective standards may no longer be in force, for example IEC 60354.

The calculation formulae, corresponding to the diverse standards, are also different and, consequently, the results should be different, too. On the other side, sometimes there is no correlation between the algorithm used by the transformer unit manufacturers to calculate the long time and emergency overloads, respectively, and the algorithm used by the monitoring system manufacturers.

Under these conditions, it is the user who establishes the way the monitoring installation indications should be correlated with the loading regime of the transformer units, especially for the short time emergency loading.

2. Mobile measurement installation and the specific measurement schedule

In order to compare the thermal model results with the ones of the monitoring systems (in this case Qualitrol IED 509-100) a measurement installation has been designed and developed. The installation acquires and processes the parameters that are monitored (ambient temperature, top oil temperature, the secondary current of the current transformer of the bushings and the winding temperature, calculated by the monitoring system).

Fig. 1 presents the utilized block diagram of the measurement installation. The monitored parameters are: the top oil temperature, the load current and the ambient temperature.

The data on the top oil and the winding temperatures are taken over from the monitoring systems and it is measured by means of a PT100 resistance probe with three conductor connection. The PT100 probe is situated in the thermometer pocket on the top of the tank. Knowledge of the top oil temperature allows the calculation of the hot spot temperature, and the overload possibilities of the respective power transformer unit.

For measuring the load current high voltage bushing current transformers are used. Knowledge of load current allows the calculation of the actual power that is used in the thermal model. The hot spot temperature can be determined by load current and top oil temperature.

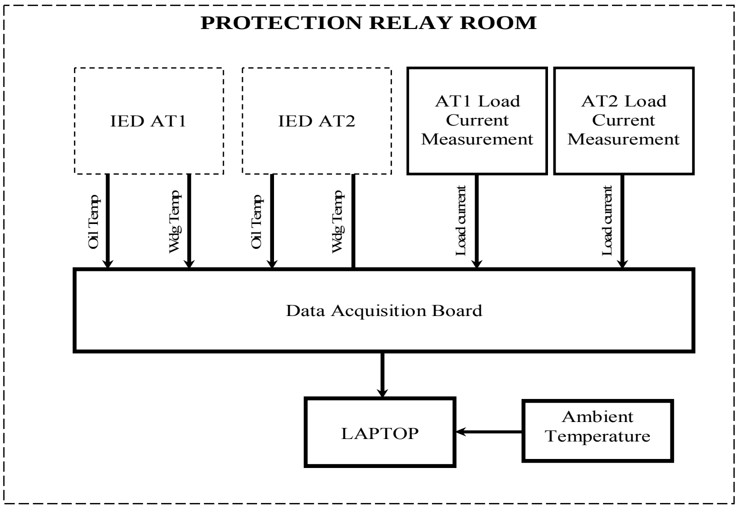

Fig. 1. The block diagram of the measurement installation

The measurements have been carried out on two 200MVA (220 / 110kV) transformer units according to the following schedule (Fig. 2):

- Parallel operation of AT1 and AT2 for about 48 hours;
- AT1 disconnection and load transfer to AT2, the latter operating under this regime for 24 hours;
- AT2 disconnection and load transfer to AT1, the latter operating under this regime for 24 hours;
- AT2 reconnection and return to the normal parallel operation of the two transformer units.

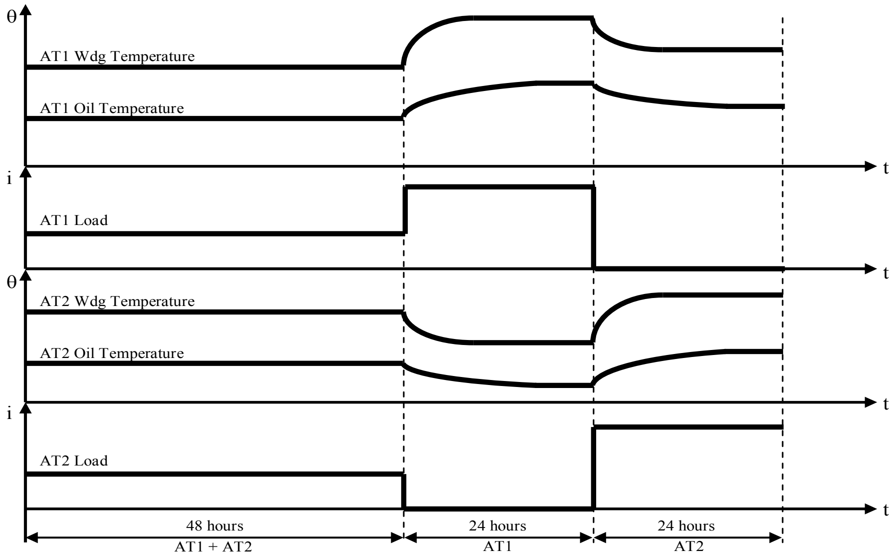

Fig. 2. Measurement schedule

3. Applications developed for the monitored parameter recording and processing

The TrafoLoad application, that is further presented, records the evolution with time of the parameters monitored by the Qualitrol IED 509–100 equipment. The user interface is given in Fig. 3. This window presents the evolution of each of the recorded parameters in a graphical form, as well as their instantaneous values. The recorded parameters are displayed in the left panels. These parameters are:

- top panel: top oil temperatures for AT1 (red) and AT2 (blue), and ambient temperature (green);
- middle panel: winding temperatures for AT1 (red) and AT2 (blue);
- bottom panel: load current for AT1 (red) and AT2 (blue).

The panels on the right side of the user interface provide supplementary information on the application execution. Thus, the first panel enables customization of the recorded parameter representation. The color, width, and representation type of each parameter can be selected.

The second panel enables selection of the communication port, measurement interval and of the file path where the recorded data are stored. This panel also includes the COM OK indicator which validates communication with the measurement modules, LNK indicator indicating the effective measurement moment, as well as the digital indicators for the recorded parameters.

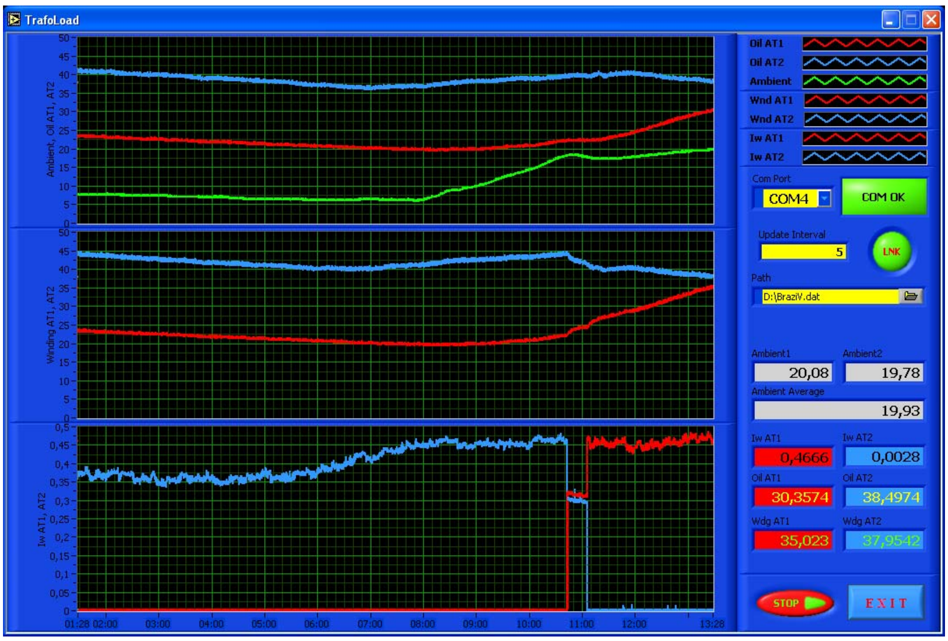

Fig. 3. Main window of recording software

The third panel enables the control of the application execution. By pressing the START / STOP pushbutton the parameter recording is initiated. The button caption changes automatically according to the status of the application. By pressing the EXIT pushbutton the application window closes.

The data is recorded in a Microsoft Excel file. If, out of different reasons (such as interruption in the supply with electricity of the computer on which the application is running) the parameter variation recording process is temporarily interrupted, then, when the recording is resumed, the data is stored in the same file, after the preceding ones.

In order to better store the data and diminish the amount of information that should be subsequently processed, the number of registered points should be diminished. To this goal, specific algorithms of the moving average type are used, according to the number of measurements recorded for each time group. This process does not lead to a loss of useful information, as the quantities stored vary relatively slowly with time, while the sampling rate is high.

The second application developed, IEC 60076-7, whose interface with the user is presented in Fig. 4, enables the analysis of the data recorded according to the thermal model in the IEC Standard at present in force, namely IEC 60076-7/2005.

The user selects the data file and then, by pushing the START button, both the measured and the calculated quantities are displayed.

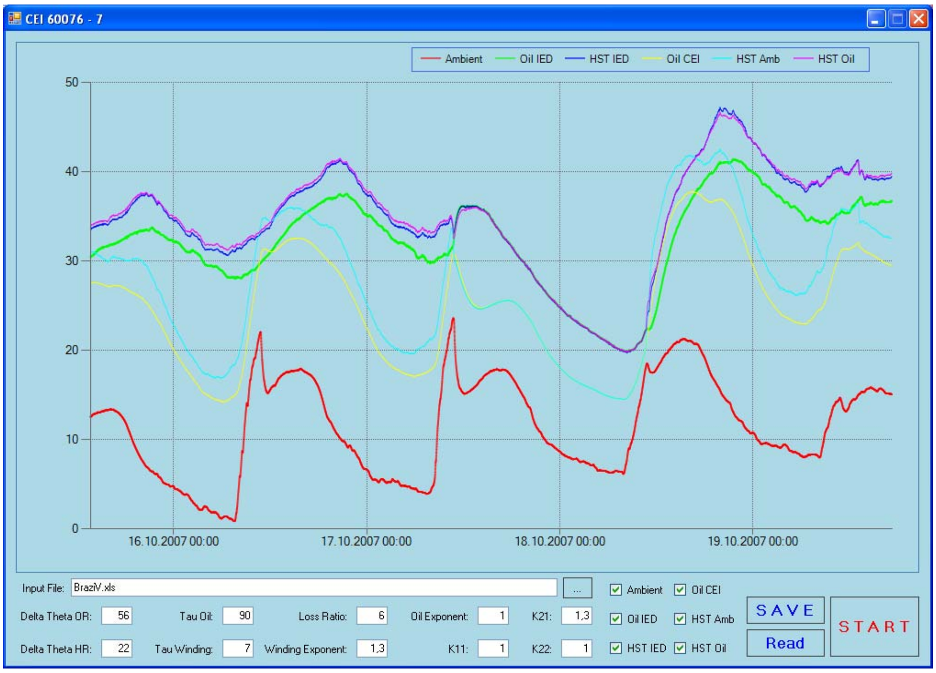

Fig. 4. Application for the analysis of the measured data

For a clearer representation of the quantities of interest, the user can select only certain quantities to be simultaneously displayed.

The calculated data are the following:

- top oil temperature with the ambient temperature and the load factor;
- hot spot temperature with the ambient temperature and the load factor;
- hot spot temperature with the top oil temperature.

This data is determined on the basis of the thermal model from IEC 60076-7 standard.

The model parameters are input in the lower part of the application. Then, these parameters can be saved in a file, the same as the calculated data by pushing the SAVE button.

After being stored, the thermal model parameters can be loaded by pushing the Read button.

4. Presentation of recordings. Comparison with the thermal model in IEC 60076-7

The recordings that were made on two 200MVA (220kV / 100kV) transformer units between 15.10.2007 and 19.10.2007 are presented below.

For each power transformer unit (AT1 and AT2) the winding hot-spot temperature was determined in three ways:

- the value indicated by the IED 509 monitoring system;
- the value calculated based on the measured value of the top oil temperature;
- the value calculated based on the measured value of the ambient temperature.

Fig. 5 (left) presents a comparison between the temperature of the winding indicated by the monitoring system and the temperature calculated on the basis of the thermal model from IEC 60076-7, starting from the top oil temperature of AT1. The top oil temperature is also presented.

Fig. 5 (right) presents a comparison between the calculated top oil temperature and the top oil temperature measured by the monitoring system, as well as the temperature of the winding indicated by the monitoring system and the values calculated on the basis of the thermal model from IEC 60076-7, starting from the ambient temperature for AT1.

Fig. 6 (left) presents a comparison between the temperature of the winding indicated by the monitoring system and the temperature calculated on the basis of the thermal model from IEC 60076-7, starting from the top oil temperature of AT2. The top oil temperature is also presented.

Fig. 6 (right) presents a comparison between the calculated top oil temperature and the top oil temperature measured by the monitoring system, as well as the temperature of the winding indicated by the monitoring system and the values calculated on the basis of the thermal model from IEC 60076-7, starting from the ambient temperature for AT2.

On each Fig. on their lower part the loading factor variation is presented, so the disconnection time interval can be clearly viewed.

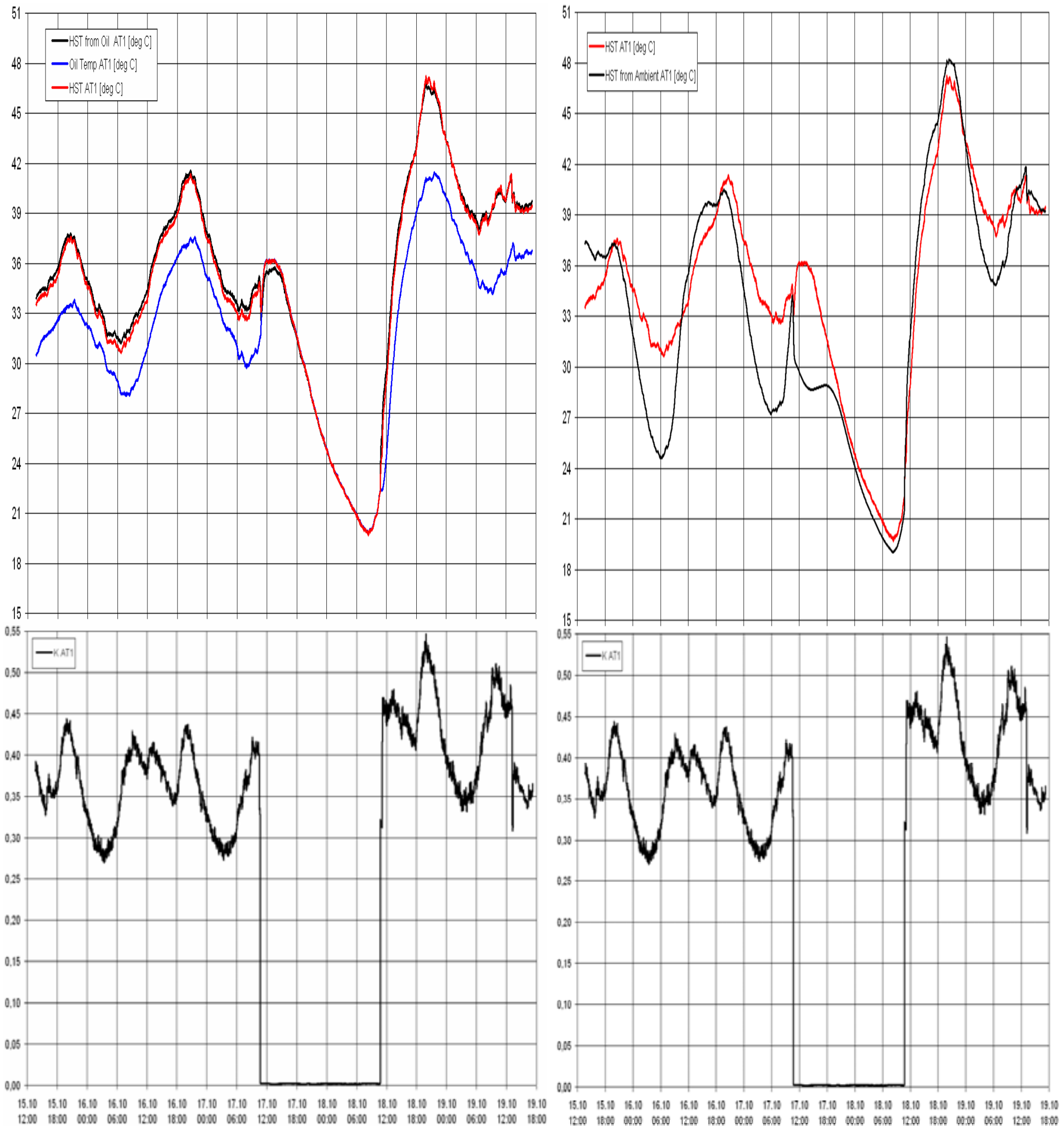

Fig. 5. Modeling of winding temperature, starting from the AT1 top oil temperature (left); Modeling of winding and oil, starting from the ambient temperature for AT1 (right)

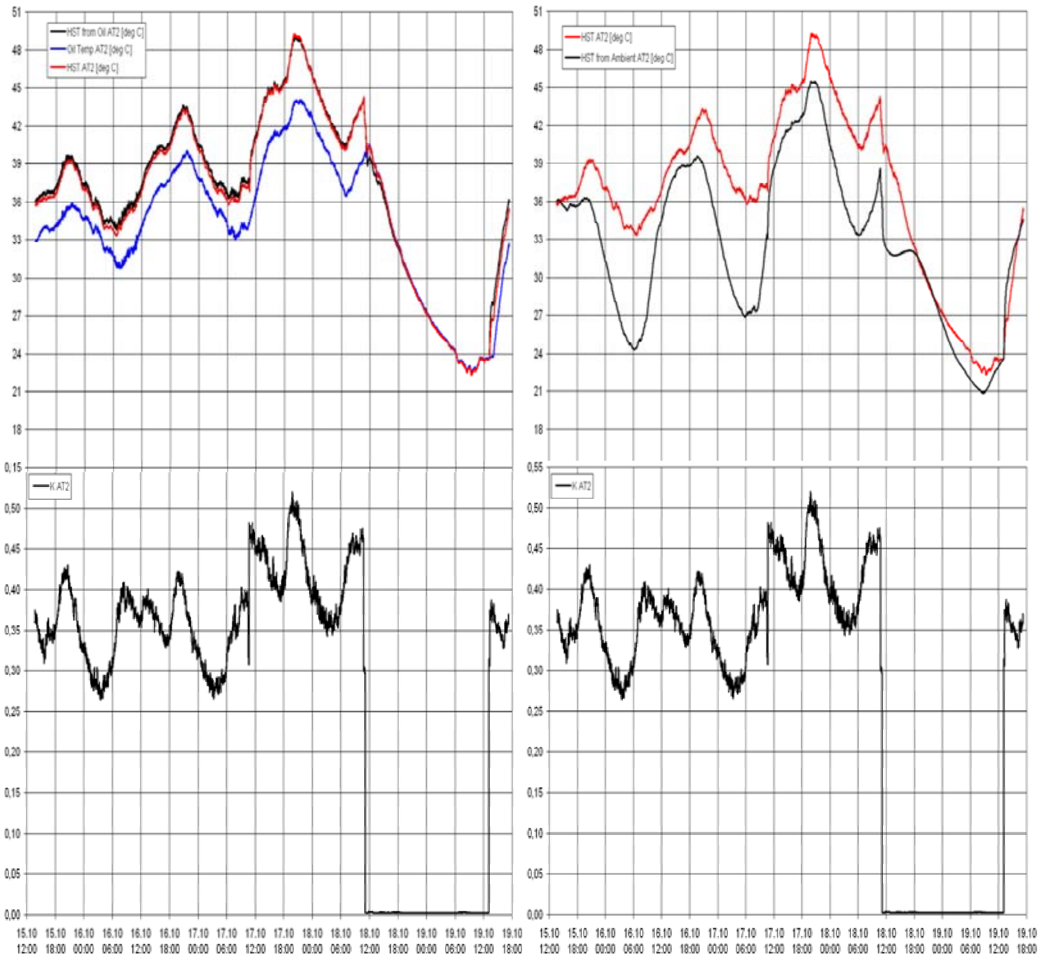

Fig. 6. Modeling of winding temperature, starting from the top oil temperature for AT2 (left); Modeling of winding temperature and oil temperature, starting from the ambient temperature for AT2 (right)

From the analysis of recorded data there results that the monitoring system provides a relatively constant hot-spot temperature gradient under quasi steady state operating conditions.

Fig. 5 (left) shows that the top oil temperature continues to increase when AT1 is disconnected, although the load is no longer present. This is due to the fact that once the transformer unit was disconnected the transformer unit cooling batteries were also disconnected. This stopped the oil circulation in the transformer tank. Therefore, the hot oil rose to the top part of the tank, where the measuring transducer is located. In the case of AT2 disconnection (Fig. 6, left) a cooling battery was kept in operation. Thus, the top oil temperature has slightly increased, and then it began to decrease, sooner than in the AT1 case.

The loading variation, as compared with the parallel operation, has been relatively low, and the loading factor did not surpass the value: K=0.5 for most of the recording period of time. Although the load did not register important variations, the experiments pointed out the reliability of the developed installation and proved it was possible to use it on site.

The analysis of the thermal models points out that the indication of the monitoring system relating to the winding temperature is almost identical with that calculated on the basis of the thermal model. There results that this monitoring system observes the IEC 60076-7 as the monitoring system also carries out the winding temperature calculation starting from the direct measurement of the top oil temperature, without considering the ambient temperature.

In the case of both top oil and winding temperature modeling starting form the ambient temperature, a rather important difference from the indication of the monitoring system is noticed. The ambient temperature has not been measured by means of a specialized ambient temperature transducer, but by means of a transducer measuring the top oil temperature, mounted within a ventilated closed space made of plastic. That is why, in case top oil and winding temperature modeling is envisaged, starting from the ambient temperature, the way the latter is measured is very important. At the same time the thermal model parameter setting has to be carefully considered, as the parameters characteristic of a certain type of transformer unit are unknown in most of the cases, so that they have to be calculated or determined by the manufacturers of the respective transformer units.

The ambient temperature measurement is necessary for the pre-determination of the top oil temperature, for the loading regimes scheduling, as well as for the assessment of the cooling system condition.

5. Conclusions

On the basis of the above mentioned information the following conclusions can be drawn.

The on-line or off-line monitoring systems are an essential component of the high voltage electrical equipment management system for the power grid operators as they provide instant information about their condition.

Therefore, these monitoring systems must be tested in order to be sure that they provide reliable information.

The mobile installation developed enables the monitoring systems testing in operation, on site.

The differences between the information provided by the monitoring system and those resulting from the thermal model of IEC 60076-7/2005 are insignificant, if we start from the top oil temperature in order to establish the winding temperature.

The differences between the monitoring system indication and the one resulting from the thermal model given in IEC 60076-7/2005 are significant, if we start form the ambient temperature in order to establish the winding temperature. This is partially due to the ambient temperature measurement method, on the one hand, and not-knowing all of the thermal model parameters from IEC 60076-7, on the other hand.

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